MODIS Team Member - Semi-annual Report

Marine Optical Characterizations
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SUMMARY

the Marine Optical Characterization Experiment (MOCE) Team continues to acquire and provide at-sea observations for MODIS initialization and calibration tasks conducted with the University of Miami team members. The Marine Optical Buoy (MOBY) system continues to support the Marine Resolution Imaging Spectrometer's (MODIS) vicarious activities with the daily acquisition of basic optical and meteorological observations coincident with TERRA's overpasses. During this period, the team conducted three field campaigns in Hawaii in support of the MOBY/MOCE projects. These cruises, designated MOBY- L74 through MOBY- L81 and Oahu-2, serviced the MOBY218, MOBY219, and MOBY220 systems. Additionally, the team is continuing to provide the SeaWiFS Project observations for their validation and long-term calibration tasks. The collaboration with NIST personnel in conducting stray-light characterizations of the MOBY/MOCE optical systems has resulted in reprocessing the MOBY matchup data base for both projects. A major effort was conducted on evaluating the multitude of calibration iterations and their impact on the derive products.

A summary of the team activities during this reporting period is shown in Figure 1 and the major efforts were as follows:

- Completed the retrieval and deployment of the moored watch buoy.
- Completed the retrieval and deployment of MOBY218, MOBY219, and MOBY220.
- Obtained several ocean color validation sets with coincident MODIS and SeaWiFS overpasses.
- Conducted FOS and MICROPRO concurrent *in situ* observations for calibration comparisons.
- Conducted, with NIST personnel, an *in situ* Raman scattering experiment utilizing a 10 watt 532 laser.
- Initiate and completed FOS thermal characterizations.
- Performed site maintenance and completed replacement of the MOBY tent fabric.
- Hosted and participated in the NASA EOS Aqua educational outreach webcast at the MOBY operations site.
- Completed a new suite of data processing programs for the AC-9 and fluorometer along-track observations.
- Reprocessed five MOBY deployment data sets for stray-light corrections and provided these data to the SeaWiFS and MODIS projects.
- Quality controlled the pigment data for the MOCE-5 experiment and corrected the high concentration HPLC observations.

- Revised the pigment and total suspended matter algorithms (Version 3.0) for the new MODIS processing version scheduled to be delivered in early March
- NIST/MLML personnel continued the stray-light characterizations on MOBY and the Fiber Optic Spectrometer (FOS).
- Reprocessed ten MOBY deployment data sets with stray-light corrections. These corrected versions have been provided to the SeaWiFS and MODIS projects and form the basis for both systems calibration changes and reprocessing
- Completed modifications (Version 3.1) of our MODIS pigment and total suspended matter algorithms to include nominal stray-light corrections for the blue water spectra. These modifications are being used in the present MODIS reprocessing code version 4.2.
- Completed a radiance distribution experiment with Ken Voss (University of Miami) with his new distribution camera system and our suite of bio-optical instruments.

FIELD OPERATIONS

The **MOBY- L74** (January 14 - February 7, 2002) recovery and replacement cruise occurred January 21 - 27, 2002 aboard the R/V Ka'imikai-o-Kanaloa. The primary purpose of this expedition was to exchange the mooring buoy with meteorological instrumentation, recover MOBY218 and deploy MOBY219, conduct MOCE data collections, perform CIMEL site maintenance, and work with NIST personnel on MOBY stray light correction algorithms. In addition to our team members, personnel from NIST, Moss Landing Marine Laboratories, Mooring Systems Inc., and Hawaiian Rafting Inc. participated in this cruise:

NOAA - Dennis Clark, Ed Fisher, Chris Kinkade, Eric Stengel, Marilyn Yuen-Murphy
QSS/NOAA - Larissa Koval, Mike Ondrusek
DSTI/NOAA - Yong Sung Kim
MLML - Stephanie Flora, Rachel Kay, Darryl Peters
MLML/QSS/Hawaii - Mike Feinholz, Mark Yarbrough
MLML/Hawaii - Terry Houlihan
NIST - Steve Brown, Carol Johnson
Hawaiian Rafting Adventure (HRA) - Steve Juares
Mooring Systems, Inc. - Peter Clay, Doug Dooner

The ship departed Snug Harbor, Honolulu, Hawaii on the morning of January 21, stopping for two bio-optical stations during transit to the MOBY mooring site. Severe winds prevented recovery of MOBY 218 on the 21st; howevere, MOBY 218 was recovered in the morning of January 22 (Figure 2). The deep sea mooring/ MOBY weather station, LMOB201, was replaced with LMOB202 in the afternoon (Figure 3). This version of the weather system is similar to LMOB201, with the exception of WETLabs C-Star transmissometer, which was added to the underwater suite of instruments. An anti-fouling canister was placed in-line with the underwater instruments to retard biofouling of the optical and the conductivity sensors. This canister is also an update to the previous deployment configuration.

The ship returned to the dock late on January 22, MOBY 218 and LMOB201 were unloaded, MOBY 219 and more equipment and personnel were loaded, and the ship departed on leg two for Lanai. MOBY 219 was deployed on January 23 at the Lanai mooring site. Data collection for bio-optical algorithm development was accomplished only on 23 January; both satellite (MODIS and SeaWiFS) overpasses were ~ 100 nm away from MOBY. Nearly 100% cloud cover precluded data collection during the rest of the cruise. Fiber Optic Spectrograph (FOS) and MICROPRO concurrent *in situ* observations were conducted for calibration comparison. FOS thermal characterizations were initiated. Ten seawater samples for particulate and detrital absorption spectra and 11 water samples for colored dissolved organic material (CDOM) absorption spectra were collected and analyzed. CIMEL site maintenance was performed on January 24 and an initial set of diver reference scans occurred on January 27.

During this trip, bulk water pigment samples were collected and analyzed, concurrent with MOCE data acquisition. Seventy-two fluorometric pigment samples were run at sea, with surface values ranging from the usual 0.09 - 0.11 mg m^{-3} near the MOBY site to 0.25 to 0.30 mg m^{-3} inshore, close to the Molokai coastline. Fifty-four 4-liter HPLC pigment samples were also collected and shipped under LN_2 to CHORS for analysis in San Diego. Both MOBY-L74 pigment data sets were submitted to the MOCE database. All fluorometric samples were run on both the MOBY and the Mill Creek (high gain - turbid water) fluorometers. The fluorometers showed a linear 13% difference in values at this narrow range of chlorophyll *a* values, similar to previous comparisons, with a correlation coefficient of 0.99.

We also completed a new suite of data processing programs for the AC-9 and fluorometer along-track observations. Five MOBY deployment data sets were reprocessed for stray light corrections and these data were provided to the SeaWiFS and MODIS projects. The pigment data for the MOCE-5 experiment were quality controlled and the high concentration HPLC observations were corrected.

In February, we hosted and participated in a NASA EOS Aqua educational outreach webcast at the MOBY operations site in Snug Harbor, Honolulu, Hawaii. Drs. Marie Colton, Eric Bayler, and Eddie Bernard, Director PMEL, visited the MOBY site and discussed the future role of the MOBY project within a NOAA context.

During **MOBY L-75** (March 6 - 8, 2002), MOBY, Meteorological station (LMOB), and CIMEL maintenance was performed. Terry Houlihan flew to Maui on March 6 and departed Lahaina the following day aboard the M/V Ho'okela with Captain Kim Miyaki and Mate Chris Whittingham. The LMOB202 underwater sensor package - CTD, Fluorometer, Transmissometer - was recovered and the MOBY219 ARGOS transponder replaced on March 7. HRA staff took Mr. Houlihan to the mooring on the 8th, where he replaced the LMOB202 underwater sensors removed on the previous day. The Lanai CIMEL instrument was serviced on the 8th.

During **MOBY-L76** (March 10 - 12, 2002), diver lamp calibrations on MOBY219 were performed. Mark Yarbrough flew to Maui and charged diver reference batteries on March 10. HRA staff worked with Mark Yarbrough on the 11th to perform before-cleaning diver reference lamp scans on MOBY

219. They returned on March 12 to clean MOBY 219 underwater optical collectors and perform after-cleaning diver reference scans.

MOBY L-77 occurred April 8 - 18, 2002. The primary purpose of this trip was to replace the fabric panels on the MOBY Fabric Building Structure (FBS) or tent. The original tent (75') skin, which was installed in 1993, was completely replaced. All three of the cooling turbines at the top of the tent were replaced and waterproofing around the base of the tent was finished.

NIST/MLML personnel continued the stray-light characterizations of the MOBY optical systems and FOS. FOS thermal characterization data acquisition was completed. Six MOBY deployment data sets were reprocessed with stray-light corrections. These corrected versions have been provided to the SeaWiFS and MODIS projects and form the basis for both systems calibration changes and reprocessing. Modifications (version 3.1) of our MODIS pigment and total suspended matter algorithms were completed to include nominal stray-light corrections for the blue water spectra.

Mark Yarbrough and Terry Houlihan flew to Maui on April 8 to charge diver reference batteries. With assistance of HRA personnel they worked at MOBY219 to sample and filter seawater and perform before-cleaning diver reference lamp scans on April 9. They returned on April 10 to sample more seawater, clean underwater optical collectors, and perform after-cleaning reference scans.

MOBY-L78 was designated for CIMEL instrument maintenance. HRA personnel serviced the Lanai CIMEL instrument on April 22, 2002.

MOBY-L79 occurred May 9 - 10, 2002. Diver reference batteries were charged on May 8. Our personnel worked at the MOBY mooring site to filter four water samples for HPLC analysis and performed before-cleaning diver reference lamp scans. They returned on May 10 to collect two more water samples, clean underwater optical collectors and perform one after-cleaning diver reference scan.

OAHU-2/MOBY-L80 field experiments occurred May 13 - June 6, 2002. The first part of this trip (OAHU-2) was spent performing daily small boat operations (off the coast of Oahu aboard the R/V Klaus Wyrtki), making optical measurements in support of validating MODIS and SeaWiFS satellites. Six stations were occupied during this trip with a total of 12 TSM and POC samples collected. The second leg of the trip (MOBY L-80) was spent aboard the R/V Ka'imikai-o-Kanaloa. The ship departed Honolulu, Hawaii on the morning of May 21, deployed MOBY220 at the Lanai mooring site, and recovered MOBY219. Figure 4 depicts the MOBY219 retrieval. On May 22, bio-optical station #1 was conducted at the MOBY site and initial diver reference scans were performed. Station #2 was completed on May 27 before returning to Honolulu harbor. Twelve water samples were also collected and filtered for POC and TSM analysis.

One of the primary purposes for this trip, besides replacing MOBY, was to fully characterize the underwater radiance distribution with solar zenith angle. During the spring equinox, the sun passed directly over head in Hawaii allowing us to measure the underwater radiance distribution from morning to evening, covering all possible solar zenith angles that MOBY might possibly encounter throughout the year. Nine days were spent aboard the R/V Klaus Wyrtki with Ken Voss from the University of

Miami, measuring the underwater angular distribution with NuRads (Fig.5). Despite some rough weather at the beginning of the nine days and some afternoon clouds towards the end, we were able to collect images of the underwater angular distribution at all MODIS wavelengths at all desired solar zenith angles. To compliment the NuRads data, we also collected pigment, TSM, and POC samples and made optical measurements with SIS, FOS, and MICROPRO. Dr. Voss is currently characterizing the underwater radiance distribution with solar zenith angle aboard his sailboat in Maine.

MOBY-L81 occurred June 6 - 7, 2002 and was dedicated to weather station and CIMEL maintenance. Our personnel flew to Maui on June 6 to setup the LMOB202 underwater instrument suite, and sailed to the Lanai mooring site to install the SBE CTD, SeaStar Transmissometer, and WeyStar Fluorometer. The Lanai CIMEL instrument was serviced on June 7, 2002.

RADIOMETRIC STANDARDS & RADIOMETERS

Team personnel stationed at the NOAA operations facility at Snug Harbor, Hawaii continued maintenance of our NIST-traceable radiometric standards and performed calibrations of our radiometers. In January 2002, Mike Feinholz modified the OL450 power supply to monitor output photodiode voltage for logging during lamp usage. At the end of June 2002, the following summary of calibration sources can be reported: the OL45 radiance source had 13.3 hours use since its December 2001 lamp #3 calibration; the OL420 radiance source had 28.5 hours use since its February 2000 lamp #6 calibration; the F453 FEL irradiance standard had 37.4 hours use since its July 1998 NIST calibration; F454 had 18.1 hours use since its February 2001 calibration; and F471 had 3.6 hours service since its February 2001 calibration. The Standard Lamp Monitors, SLMs, were included in the annual intercomparison with NIST detector/sources during NIST-2002-01 in January 2002 at Snug Harbor, Hawaii. The NOAA SLM's and EOS VXR radiometers viewed the NIST NPR, MLML OL425, and MLML OL420 sources to validate precision and repeatability of source radiance calibrations. Preliminary results suggest the 425 radiance calibration is within expected uncertainties but we had one anomalous measurement of the 420 at the far-red VXR wavelength. The SLMs are scheduled for return to NIST in August 2002 for calibration on SIRCUS to repeat the irradiance characterization. Also scheduled in August is the recalibration of the OL420 and OL425 spheres by NIST.

Radiometric calibrations during the reporting period included:

1. Predeployment calibration of MOBY219and MOS205cfg07 in January 2002
2. SLM vs VXR intercomparisons during NIST-2002-01, FOS, MOBY219 LuTop, MOBY219 LuBot and LuMid in January 2002
3. Postdeployment MOBY218/MOS204cfg06 in January and March 2002
4. Post- MOBY-L74 MOS202cfg08 and SIS101cfg04 in March 2002
5. Predeployment MOBY220 in May 2002
6. Post-MOBYL80 FOS in June 2002

A detailed listing of calibrations and maintenance for each standard and instrument are provided in Appendix 1.

STRAY LIGHT CHARACTERIZATION

Stray light is generated by forward-scattered (haze) and isotropic (diffuse) radiation from the single MOS holographic grating plus any light scattered from other optical elements. This leads to MOS ?out-of-band" signal. The NIST Spectral Irradiance and Radiance Calibration facility using Uniform Sources, (SIRCUS), which produces spatially uniform, monochromatic, broadly tunable radiance, was used to accurately determine ?in-band" and ?out-of-band" components in measured MOS signals. High resolution scans at 0.2 nm intervals were measured over spectral ranges to define the spectrograph's in-band profile, to be used in the Stray Light Correction Algorithm. Additionally, the NIST "Colored Source" OL420 radiance source was utilized with and without colored glass filters to establish a validation data set for correcting broadband blue-rich and green-rich spectra via a calibration response established with a red-rich source. Finally, temperature-response characterization has begun on MOS2 and FOS with the assistance of NIST personnel and equipment.

A preliminary MOS Stray Light Correction Algorithm was developed by NIST and MLML researchers to separate in-band and out-of-band components from MOS, MOBY, and FOS measured signal at each detector element. This correction is applied to both responsivity measurements of a calibrated radiance source and in-water upwelled radiance measurements. High-resolution SIRCUS laser scans were inverted and fit to a Lorenzian function to produce the SSF, or slit scattering function. Second order reflections observed in the MOS spectrographs and zero-order light in the FOS were also modeled and included in the SSF. Removing the in-band portion yields an out-of band SSF. The out-of-band SSF is convolved with uncorrected response or signal, and the integral estimates the stray light component at each channel. Subtracting the stray light gives ?corrected" values. Corrected values are then used as input and the procedure is iterated until a steady state solution is reached. The validity of the algorithm was checked by applying uncorrected and corrected responsivities to measurements of the NIST Colored Source and comparing to NIST determined source radiance. Preliminary corrections presented to the SeaWiFS and MODIS projects indicate a 7-9 percent decrease around 550 nm.

During the reporting period, NIST researchers Carol Johnson and Steve Brown returned to Hawaii four times to continue stray-light characterizations and algorithm development. These experiments were termed NIST-2002-01, -02, -03, and -04.

During the first trip **(NIST 2002-01)**, which took place January 14 - February 7, 2002, NIST personnel studied stray light effects for both MOS systems used in the buoys (MOS204 and MOS205). In order to do both systems, this experiment was scheduled around the mooring and buoy swap. This meant that the stray light measurements were in addition to the pre- and post-deployment instrument calibrations.

The MOBY instruments were used to acquire OL420 Colored Source (CS) for validation of the stray light correction algorithm. The CS was used to measure MOBY219 LuMOS, MOBY219 LuTop, and FOS Lu. The latter task made it necessary to calibrate Lu FOS using MLML OL425.

The Fastie Ebert visible spectroradiometer (VisSR) was used to determine the spectral radiance of the CS. The VisSR was calibrated twice using the NPR with lamp #3 on January 21 and January30. The VisSR measured the CS with filters BG28, PER, I400, I700, and I750. Two measurements of the PER configuration were done on January 21-22. Because of discrepancies with the VisSR results, the VXR was used on January 30 to measure the PER and BG28 configurations.

In order to characterize the MOS spectrographs in the various configurations for reflection peaks, fixed wavelength lasers and tunable lasers were used (see Table 1 for the values). The tunable lasers were in a blue region (428 nm to 438 nm) and a near infrared region (700 nm to 782 nm). The data were acquired for MOBY219 (LuTop) and MOBY218 (LuMid and LuBot).

Using the XS SIRCUS data acquired in October 2001 (NIST-2001-04), SLC model parameters were developed for FOS. Additional tests were identified and performed for temperature characterization and for quantifying the cross coupling between Ed and Lu.

In order to determine SLC model parameters for MOBY219 and MOBY218, scans of MOBY219 were compared to those acquired in October 2001 (NIST-2001-04) on MOBY217.

A 10 W cw laser at 532 nm was used for *in situ* Raman scattering measurement with FOS. The study was done after dark from the aft deck of the K-O-K on two subsequent nights during MOBY-L74 (Fig 6). A Kaiser Optical 532 nm notch filer was fitted to the FOS radiance collectors. A fiber optic connected FOS to the NIST 10 W Nd:V laser, operating at 532 nm. Two features were observed in the retrieved FOS in-water signal under night-time conditions illuminated with the 532 Nd:V : a strong peak at 650 nm and a small shoulder at 680 nm. These were tentatively assigned to in-water Raman scattered light, approximately 3400 cm wave number shift due to O-H stretch mode, and to chlorophyll-related fluorescence.

In order to evaluate the accuracy of the MOBY radiance calibration sources (the MLML OL420 and OL425), the VXR and the SLM measurements were used. Each sphere was measured at two levels, and some measurements were repeated twice.

Tables 1 and 2 state the instruments used. The tables are organized sequentially and grouped according to major activity.

During the second trip **(NIST-2002-02)**, which took place April 1 - 11, 2002, MOBY220 (MOS204) had just been assembled. NIST/MLML personnel characterized the reflection peaks, acquired an in-band scan, determined the baseline with confidence, recorded images of the slit (24 x 512), and took measurements with the colored source for validation. They also competed the in-band characterization and baseline study for SIS and took data to understand the temperature dependance of the FOS radiance responsivity. Tables 3 and 4 state the instruments used.

The objective of the third **(NIST-2002-03)** experiment was to complete the characterization of the FOS. This trip occurred May 29 - June 6, 2002. As explained earlier (NIST-2002-01), some of the zero order is incident on the end of the array that is at the edge of the half of the array that is not used for the channel under study. The effect is some of the Lu flux contaminates the red end of the Ed channel. The initial stray light correction model assumed that the throughput of the zero order flux was independent of wavelength, however, it is proportional to the ratio of the grating efficiency at the measurement wavelength to the reflectance of the grating. Previously, the utility of lasers to characterize the spectral variation of this ratio was examined, and we decided Light Emitting Diodes (LEDs) were more suitable for this experiment.

During this trip, these ratios were determined using 12 LEDs, with wavelengths from 430 nm to 662 nm, for the VNIR spectrograph, and using 7 LEDs, with wavelengths from 615 nm to 930 nm, for the NIR spectrograph. On June 11- 12, three additional LEDs were measured for the NIR spectrograph (by M. Feinholz and M. Yarbrough). They were selected to fill in the gap between 660 nm and 830 nm, but were not delivered in time to be measured while NIST personnel were on site.

The variation of the FOS responsivity with temperature was re-examined this trip. Previously, the Lu and the Ed channels were studied separately, on two different trips. These data appear to be non-physical. The test was repeated using a stable source of spectral radiance for the Lu port (the NIST OL420) and a stable source of spectral irradiance (a test MLML FEL lamp) for the Ed port. These results now appear to make sense.

Finally, several days were spent reviewing the FOS algorithms, in particular the treatment of background, or offset signals. A manuscript for summary of the FOS results was outlined.

The last stray light experiment during the reporting period **(NIST-2002-04)** is taking place now (June 17 - 25, 2002) and will be described in the next semi-annual report.

MOCE/MOBY INSTRUMENTATION

FOS

The instrument development portion of the system was completed. The work is continuing to integrate the data acquisition of the four data streams produced by FOS. MLML personnel are working on a new acquisition system to replace the existing AmHolo software and Graphical User Interfaces (GUI's). The new software will acquire and average the depth, water temperature, heading, inclination, and internal temperature outputs during the Lu and Ed integration period. As we have no manufacturer's support for the AH4000 spectrographs contained in FOS, we must reverse engineer the interface. Working at MLML, we have succeeded in decoding some of the key control commands and we can parse the outputs. The remaining problems involve devising a scheme to control the hardware handshaking of the serial interface.

During MOBY L-74 refurbishing cruise, all the FOS system response data, which was in danger of being lost, were organized, and a FOS calibration history was created. This file lists every calibration data set collected, associated files and information. The same type of history file was created for FOS stray light measurements.

MICROPRO

Satlantic returned the MICROPRO unit after calibration and repair. The data glitches we have been seeing are apparently not repairable. The data glitches are easy to spot and should cause no significant problems in practical usage.

ROV

The Remote Operating Vehicle (ROV) system is due for early delivery. Aurora optics delivered the long 1 mm fibers for the FOS inputs. The positioning system transducer array mounts are in fabrication. The control console cases have been delivered and most equipment installed. All the hardware components should be delivered and ready for integration by the end of June.

MOBY

MOBY refurbishing proceeded as usual without difficulty. Mooring Systems is in process of fabricating replacement collector standoff and clamp components. A Prototype unit is due for delivery at the end of June. We have observed no loss or damage to the upper arm since adding a support cable to the upper arm. We believe the cable not only adds mechanical support to the upper arm, but also alerts boaters of the presence and location of the underwater obstruction. Currently we maintain a one year supply of long-time items (fiber optics, optical components and major mechanical assemblies). Some noncritical and locally available items are purchased as needed to maintain a two-deployment stock.

MOS

There are currently no pressing maintenance issues with the operational MOS2 instrument. MOS units 1, 4, and 5 are fully functional and receive periodic maintenance consisting of CCD head evacuation and coolant pump service. MOS2-1 is in storage, held in reserve as a profiling backup unit. NIST has returned the internal optics from MOS2-3, which will be reassembled for use as a MOBY backup unit.

WEATHER STATION

The second Mooring Weather Station (LMOB202) was installed January 2002 in conjunction with the annual replacement of the mooring buoy. This version of the weather system is similar to the previous system, LMOB201, with the exception of an additional sensor being incorporated into the data stream.

The LMOB202 receives service on a regular basis. Daily weather data are transferred to the Moss Landing facility for archiving and display on the MOBY web site. We continue to have problems with the underwater instrumentation. Damage seems to occur during maintenance of the system, resulting in the inability to gain control of the underwater package. Future *in situ* troubleshooting will be required to sort out this problem A WETLabs C-Star transmissometer was added to the underwater instruments to retard biofouling of the optical and the conductivity sensors. A problem encountered with LMOB201 occurred in middle of September 2001, where the charging system had failed to charge the batteries that supply power to the data logger. The battery pack/charge controller was removed from the buoy well and repaired. The two battery charge controllers were replaced, diodes were replaced to prevent reverse current flow and a bulkhead connector that had failed on the well cover was replaced. The package was reinstalled and the system continued to collect and transmit the weather data. Work is continuing on the mechanical integration of the third Mooring Weather System, LMOB203.

CIMEL SERVICE

The Lanai CIMEL site has operated well for the past year. The system is now due for replacement and re-calibration. We are working with Aeronet to coordinate the instrument replacement. We continue to service the instrument when possible as a part of the regular MOBY calibration work. Maintenance personnel have recently had problems setting the clock on this system. Some data loss has resulted during May and June due to this problem

The Coconut Island site has worked well for the past 6 months. The instrument received regular monthly service by personnel located at HIMB.

DATA PROCESSING

MODIS CALIBRATION AND VALIDATION

We continued to monitor the progress in the development and updating of Terra MODIS Ocean code from RSMAS at the University of Miami in order to update the data status from Provisional to Validated. The validated product is to be used by MODAPS to perform a reprocessing of MODIS data from the beginning to March 19, 2002 (Reprocessed Collection IV). Product Generation Executive (PGE09) code is used to process level 1b sensor radiance data to level 2 ocean product data. The component of PGE09 that produces ocean color data is MODCOL. Radiance corrections (rad_cor_Vxx_x) that are being produced by the University of Miami are part of MODCOL. From February to May 2002, the University of Miami developed new rad_cor versions on a near daily basis in an attempt to deliver a finalized code to MODAPS.

To monitor the progress of these code revisions, we downloaded specific Level 2 HDF data files from the University of Miami corresponding to granules over Hawaii during our MOCE and MOBY replacement cruises. Out of the potential cruise dates when we were collecting data from the beginning of MODIS to the spring of 2002, 28 days (approximately half of the days) contained zero (best) quality pixels within a 3 x 3 km box of our station during the overpass. The average of all zero quality data from each extracted 3 x 3 for each day was calculated and compared to our measured MOS and FOS data collected during the cruise. Figure 7 shows a validation of MODIS normalized water-leaving radiance data by comparison to measured shipboard data. MODIS values are 3 x 3, 1-km pixel averages centered over ship location during overpass. The MODIS data were processed by the University of Miami using the latest reprocessing code V4.2. Measured values were measured from the ship utilizing the MOS instrument at the time of overpass. All measurements were made near the Hawaiian Islands. In addition, to test our product algorithms and to show how well the new calculated water-leaving radiance values are performing, we calculated pigment, TSM and k490 values from the 3 x 3 averages and compared these values to the MODIS generated products. From the end of February to the end of April, we analyzed approximately twenty calibration iterations.

The final radiance corrections (rad_cor_V12_56) that will be implemented into PGE09 for the reprocessing code V4.2 was developed at the end of April 2002 and was validated by us using the methods described above. The new revisions have dramatically improved cross scan, mirror side and individual detector corrections over time. This resulted in more consistent data between detectors and mirrors thus reducing striping and reduced cross-scan bias allowing more continuity between adjacent granules on global maps. The new processing code was delivered to MODAPS from Miami in the beginning of May 2002. Sample data sets processed by MODAPS were made available to the MODIS Ocean science team for validation. We accomplished this validation by downloading level 2 radiance and ocean color product files from MODAPS and confirming radiance match ups and product algorithm calculations from the above mentioned MOCE list and comparing that data to the already validated Miami data. The water-leaving radiance data matched Miami's data to within 0.001 W/m^2 and our pigments matched Miami's data to within 0.001 mg/m^3.

ALGORITHM DEVELOPMENT MODIFICATIONS

During our evaluations of the bio-optical products, it became obvious that in certain areas of the globe there were significant retrieval problems with the 443nm band (these regions represented a very small portion of the global data set). These areas were associated with high concentrations and at high latitudes. Where the chlor_MODIS estimates were extremely high, we noticed that pigment_c1_total estimates (total measured HPLC pigments) were lower than chlor_MODIS (HPLC measured chlorophyll *a*), which is theoretically impossible. This discrepancy was a result of the normalized 443 nm water leaving radiance retrievals being extremely low and therefore the chlor_MODIS two band algorithm (443nm/550nm) (See Appendix 1) was computing extremely low ratios. The 3 band pigment_c1_total pigment algorithm ((443nm+490nm)/550nm) was not being impacted because with the inclusion of the 490nm band the ratios were not being impacted. In order to rectify this problem, the chlor_MODIS and TSM algorithms were reformulated into 3-band (443nm+490nm)/550 ratio algorithms which greatly reduced concentrations in these problem areas.

A further modification to these algorithms included the forcing of the pigment and TSM algorithms through the Gordon clear water radiance ratios for zero concentrations. This constraint resulted in poor third-order polynomial fits in both the high and low concentration regions of the algorithm curve and required splitting the algorithm into separate polynomial fits for low and high concentration ranges that switch at designated radiance ratios. This split algorithm was applied to our CZCS_pigment, Chlor_MODIS, pigment_c1_total, and TSM derived products.

Once the vicarious calibrations evolved to the point that consistent and reasonable global radiance values were being computed, we observed portions (<<1% area) of the globe with suspiciously low (<0.01 mg/m^3) phytoplankton pigment concentrations. At this point the MODIS ocean bands were being calibrated with the MOBY stray-light corrected data and the in-water observations were not corrected. This inconsistency was resulting in underestimating the concentrations in the product retrievals. A partial fix to this problem was to correct the clear-water radiance database using the nominal NIST derived stray-light corrections. These nominally corrected data were then used to re-compute the low concentration level regressions which resulted in significant increases in the very low concentration retrievals (30 - 50%).

MOBY

MOBY continues to acquire and transmit two files per day, coincident with SeaWiFS and MODIS overpass times. MLML personnel process these files and make the data available on our MOBY home page the day after transmission. Both files are weighted to MODIS and SeaWiFS bands. This includes the MODIS total and in-band weighted data. These data are now available on the MOBY web site.

The entire data dets for the MOBY211, 213, 215, and 217 deployments were stray light corrected and sent to Gene Eplee (NASA). As older deployments are reprocessed, they will also be stray light corrected. In February and March, Stephanie Flora created a MOBY stray light history file. Prior to doing this, all the MOBY stray light data sets were organized and processed. MOBY218 data were sent to Steve Brown (NIST) to determine the stray light parameters for the even-numbered buoys. By the end of March, the final parameters were chosen and stray light correction of even-numbered deployments began. During the April trip, all MOBY deployment were stray light corrected and sent to NASA

MOS/SIS

Mike Feinholz continues to process data from instrument calibrations and from shipboard MOS and SIS profiles using MATLAB programs customized at MLML. Two MOS/SIS profiles were performed during MOBY-L74 in January, and SIS/GSP data were acquired during Oahu-2 and MOBY-L80 cruises in May. Profiles are typically coincident with MOBY profiles and/or SeaWiFS and MODIS observations. MOS water-leaving radiances are convolved with SeaWiFS and MODIS spectral band responses for integration with our bio-optical data base (see Appendix 3 for a MOS and CTD station summary). Software refinement continued for our new PC laptop data acquisition and control system for the MOS and SIS instruments. This has now replaced the aging VAX system for laboratory calibration and shipboard experiments.

MICROPRO

The MICROPRO data were processed by similar methods applied to the SPMR. Stability of the instruments will be continue to monitored using the Gamma Scientific RS10 lamp system. A program was also written to make MICROREF data available for FOS processing. Satlantic provided new calibration files after the MOBY-L74 cruise to replace the original ones. They recommended all previous data collected be reprocessed with the new calibration files. MICROPRO processing will continue to be modified when required and as time permits.

PIGMENTS

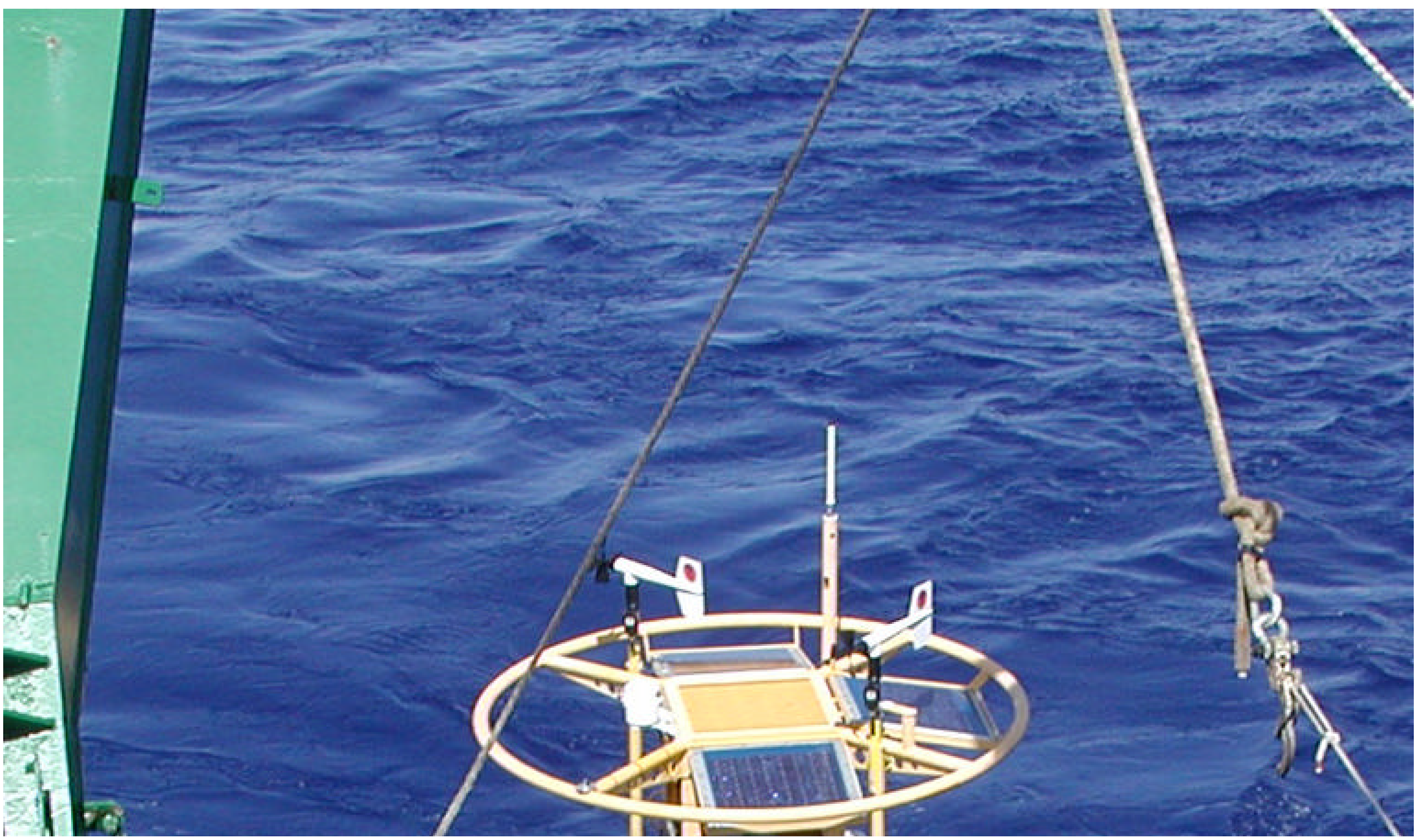
A change in Chlorophyll *a* calculation was made. The new MATLAB based processing utility was completed in January. Instead of using a varying response factor from the Chelsea fluorometer, a cruise average response factor is used. The ability to use a single response factor to calculate Chlorophyll *a* from the fluorometer is the most important feature of this new processing utility. This should keep the derived Chlorophyll product from being noisy from track-line to track-line. Because of the change in pigment derivation, all MOCE cruise pigment data are being reprocessed. Figures 8 and 9 show total pigments calculation using the new technique.

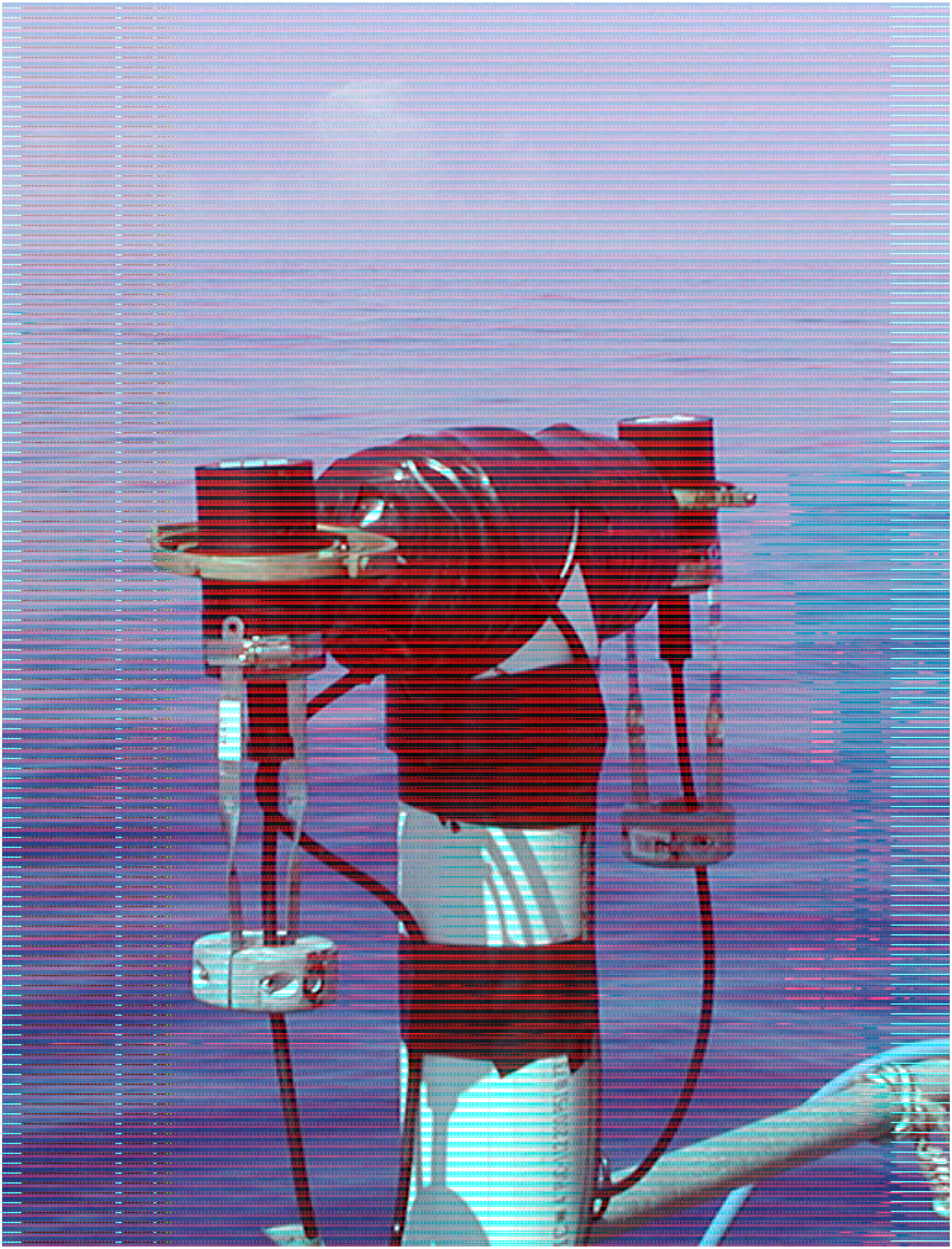
Pigment data from the MOBY-L72 cruise were analyzed. An experiment was performed to analyze variability between pigment analyses with different instrumentation and different laboratories. In addition to our usual MOBY team pigment analysis, samples were sent to both CHORS in San Diego and Dr. Robert Bidigare's laboratory at the University of Hawaii. Although there are some fluorometric samples yet to be analyzed, an interlaboratory comparison of HPLC pigments revealed a very good agreement between CHORS and UH labs. Figure 10 shows HPLC derived pigment value means and standard errors for replicates taken at a single station.

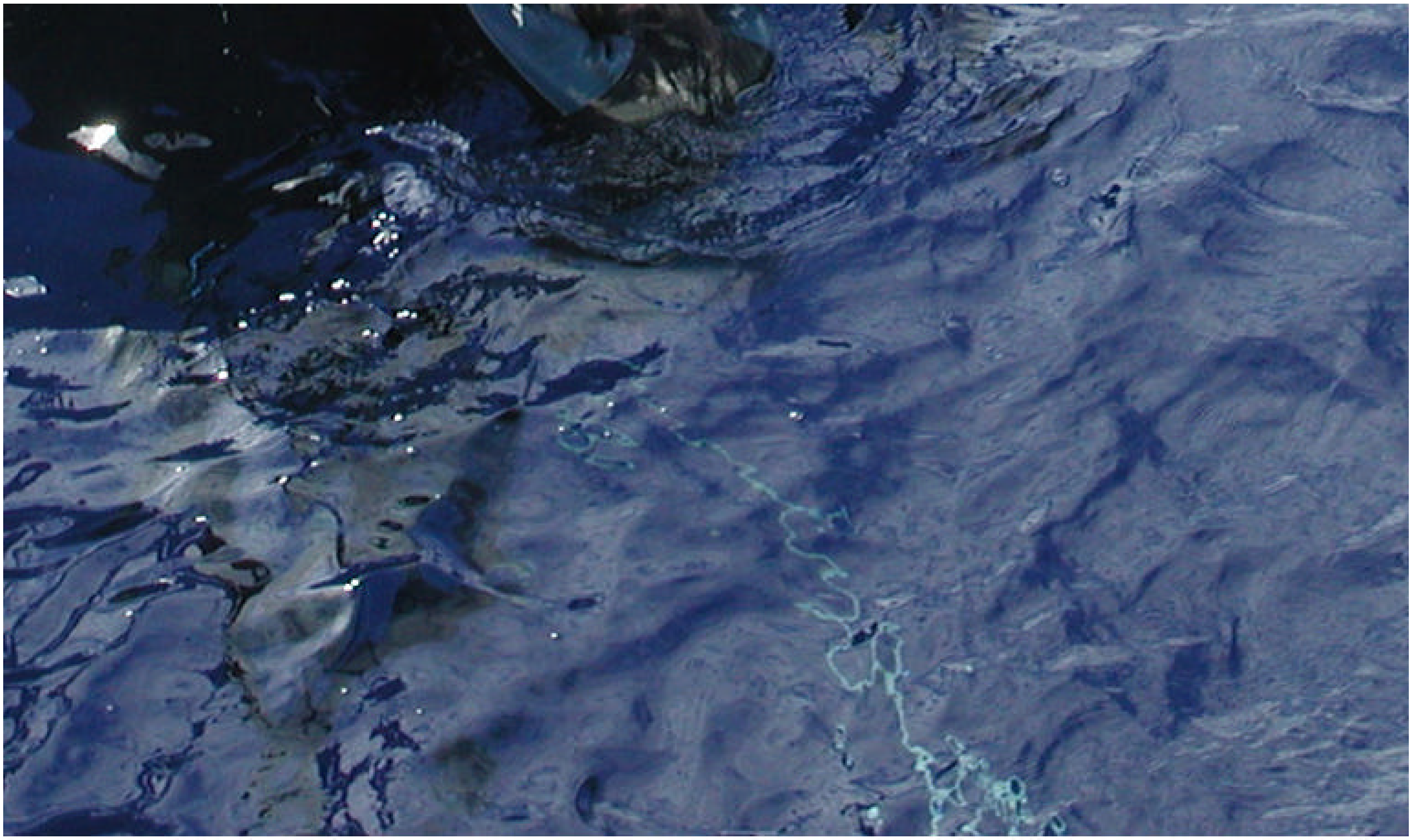
An analysis of within-pixel variability using MOCE 9 ship track fluorometric data has started. Figure 11 shows contours of chlorophyll concentrations (mg/ m^3), along with the R/V Klaus Wyrtki track in the dashed lines. The tracks are a composite of about one week of day trips off the leeward side of Oahu. Onshore-offshore 'sample transects' have been taken through the contoured data and will be matched up with a weekly composite MODIS image for a small scale variability study.

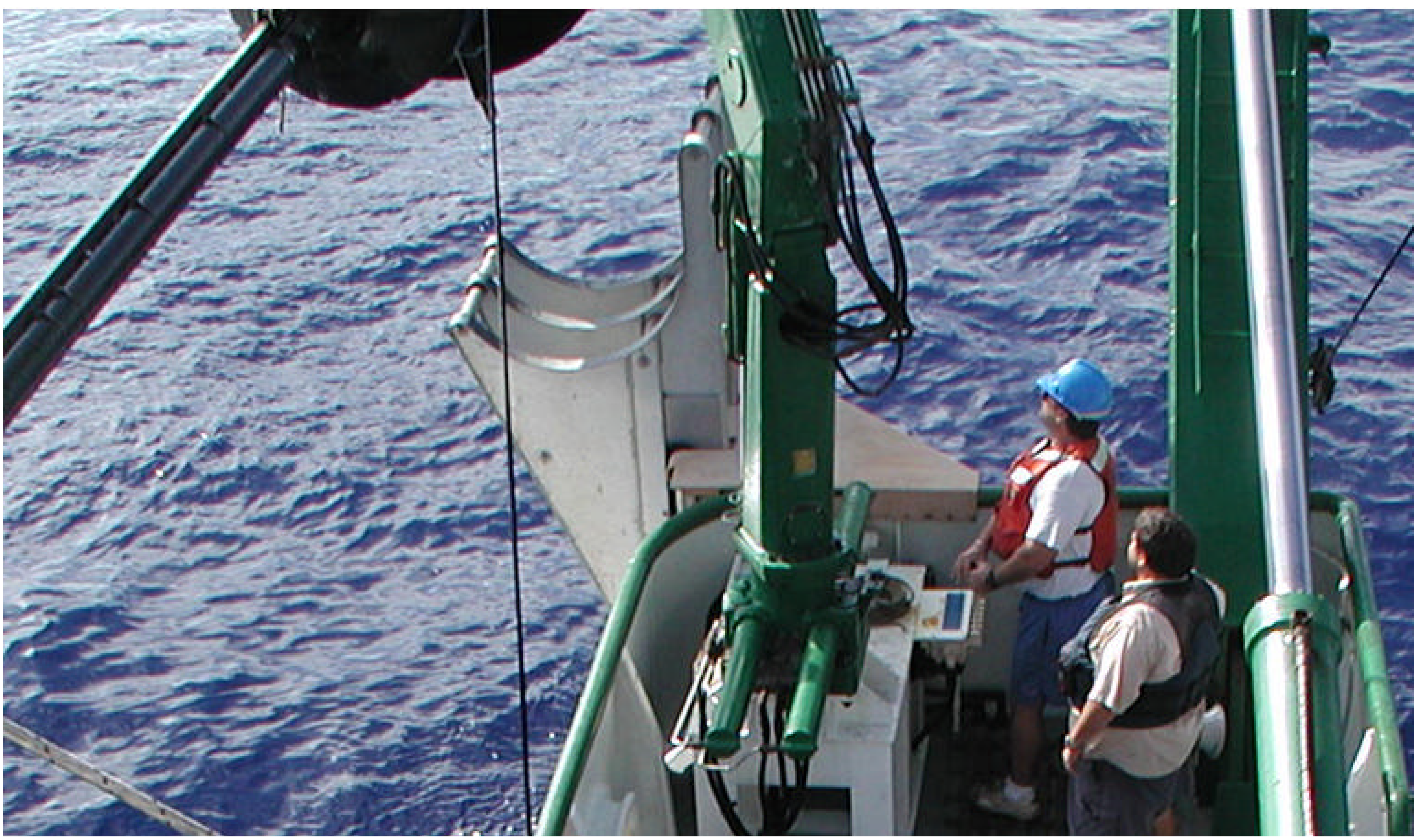
<u>MOBY CONTRACTS</u>

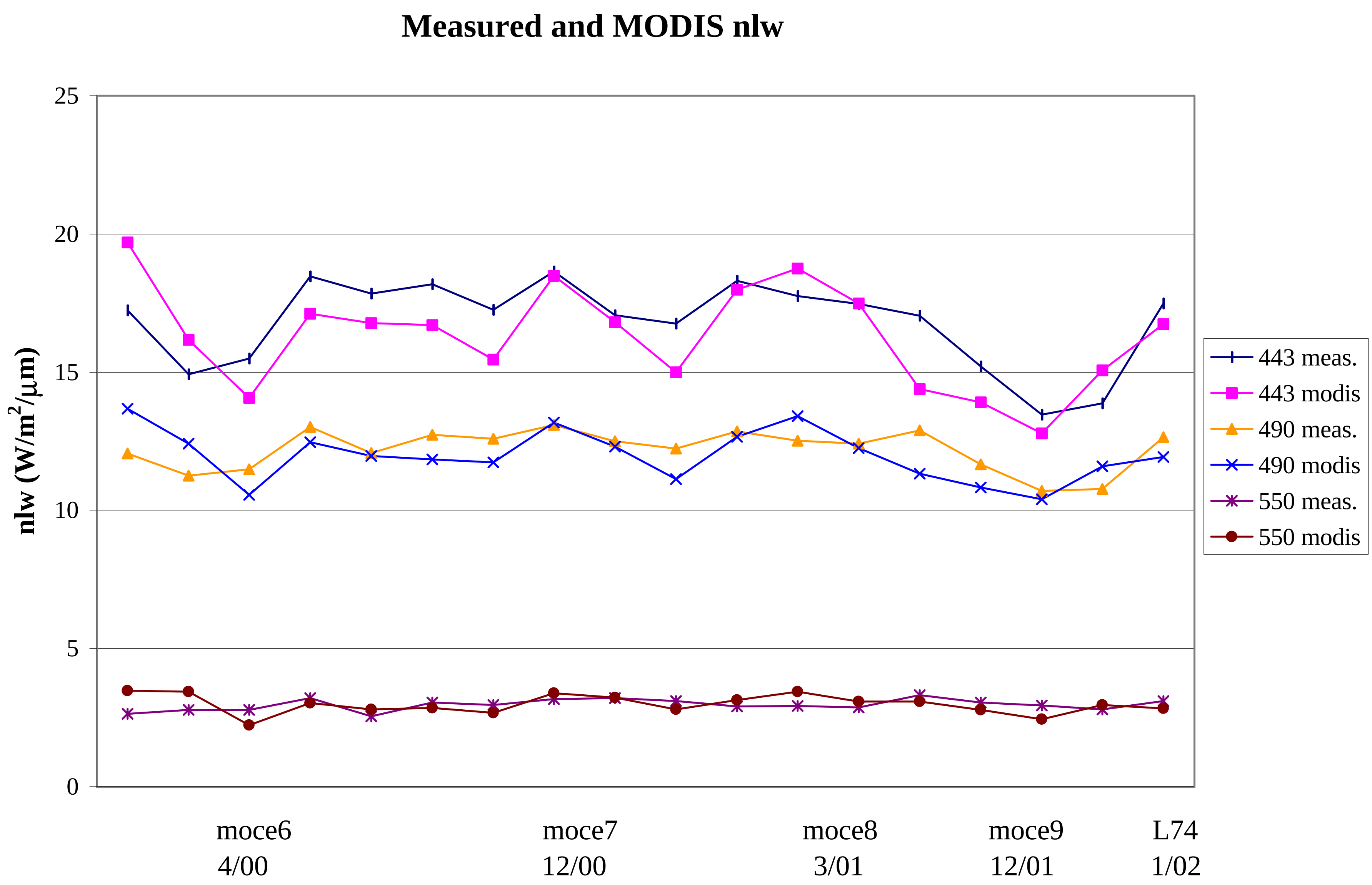
The University of Hawaii Marine Center Shore Support Contract will be renewed on July 31, 2002. The new contract amount has been increased to $49,500 in order to cover costs incurred in the machine shop. Also, the usage fee at the University Marine Facility was increased to $14,000 annually. The new contract will cover all increases and machine shop utilization.











Measured and MODIS nlw
nlw (W/m^2/μm)
25
20
15
10
5
0
moce6
4/00
moce7
12/00
moce8
3/01
moce9
12/01
L74
1/02
443 meas.
443 modis
490 meas.
490 modis
550 meas.
550 modis

Figure 7

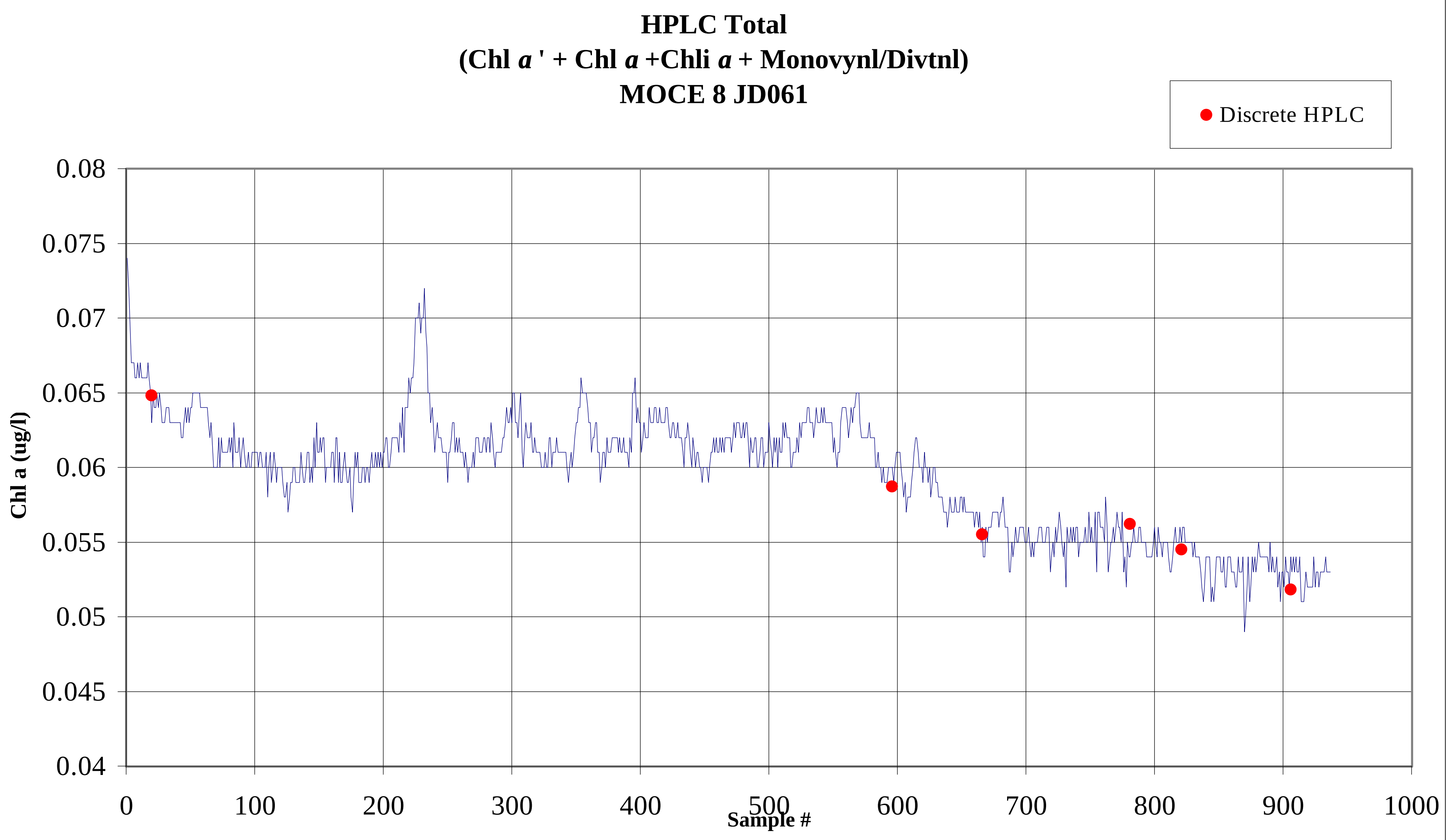

HPLC Total
(Chl *a* ' + Chl *a* +Chli *a* + Monovynl/Divtnl)
MOCE 8 JD061
Discrete HPLC
Chl a (ug/l)
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0
100
200
300
400
500
600
700
800
900
1000
Sample #

Fig.9

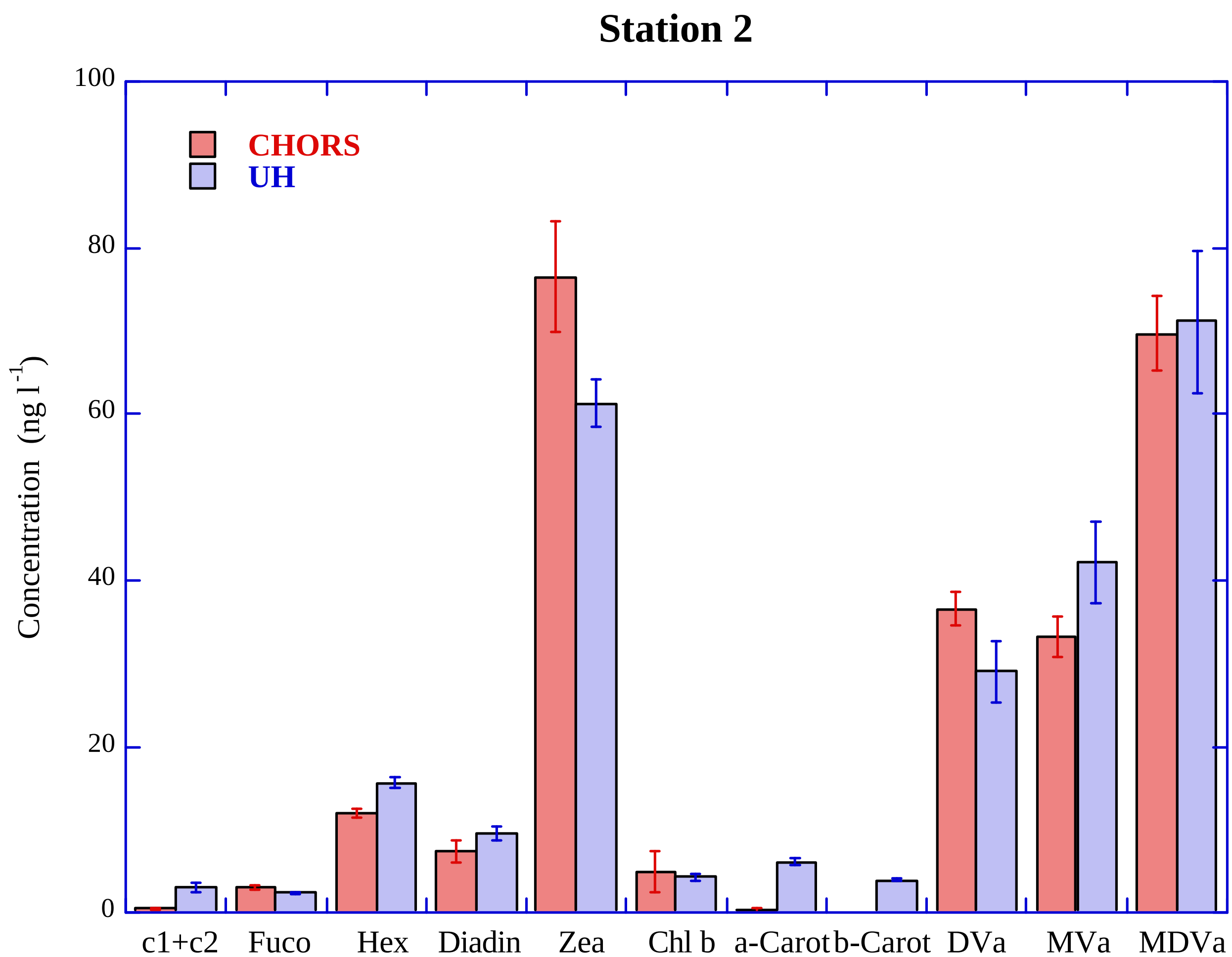


Figure 10 CHORS -UH HPLC comparison

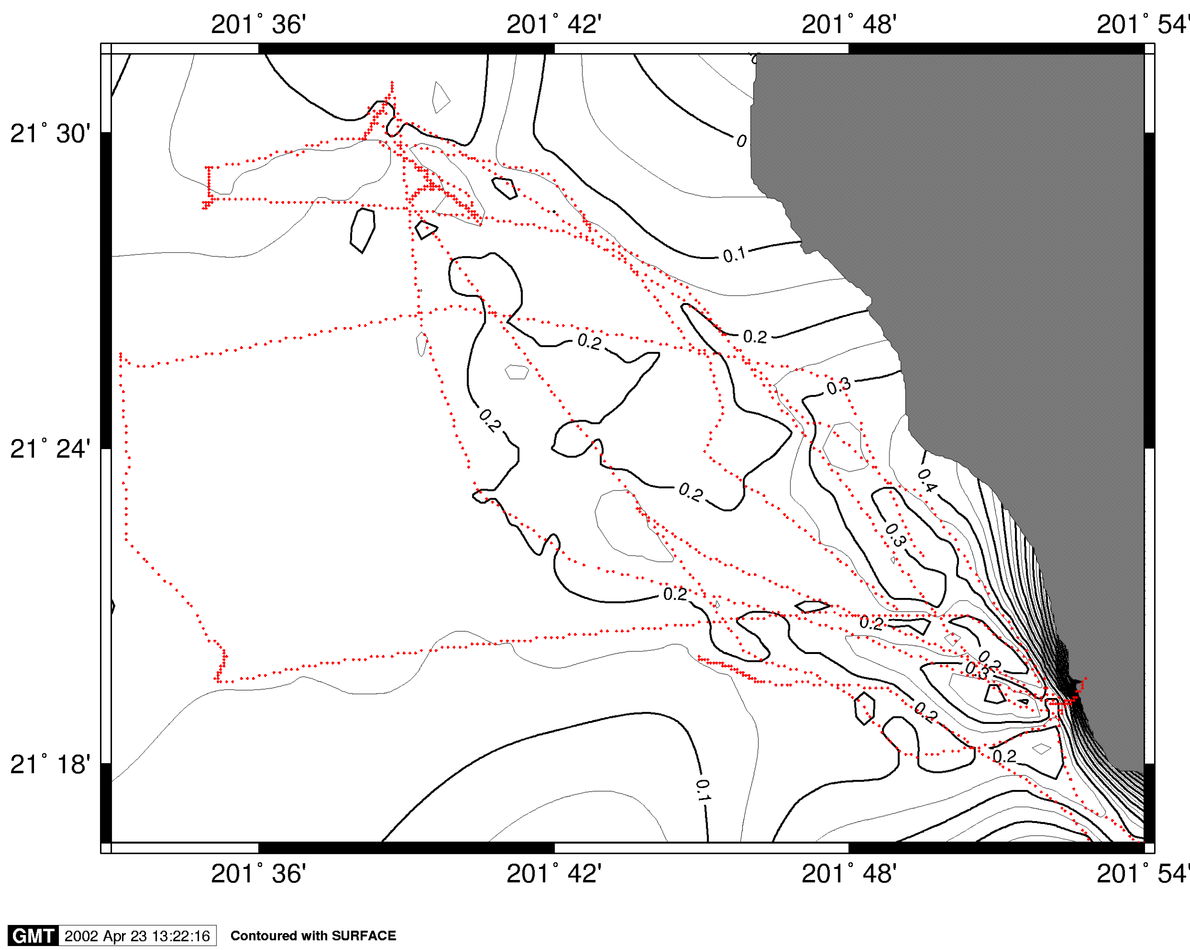


Figure 11 R/V Wyrtki ship track and contoured chl a concentrations

MOCE Team Field Activities

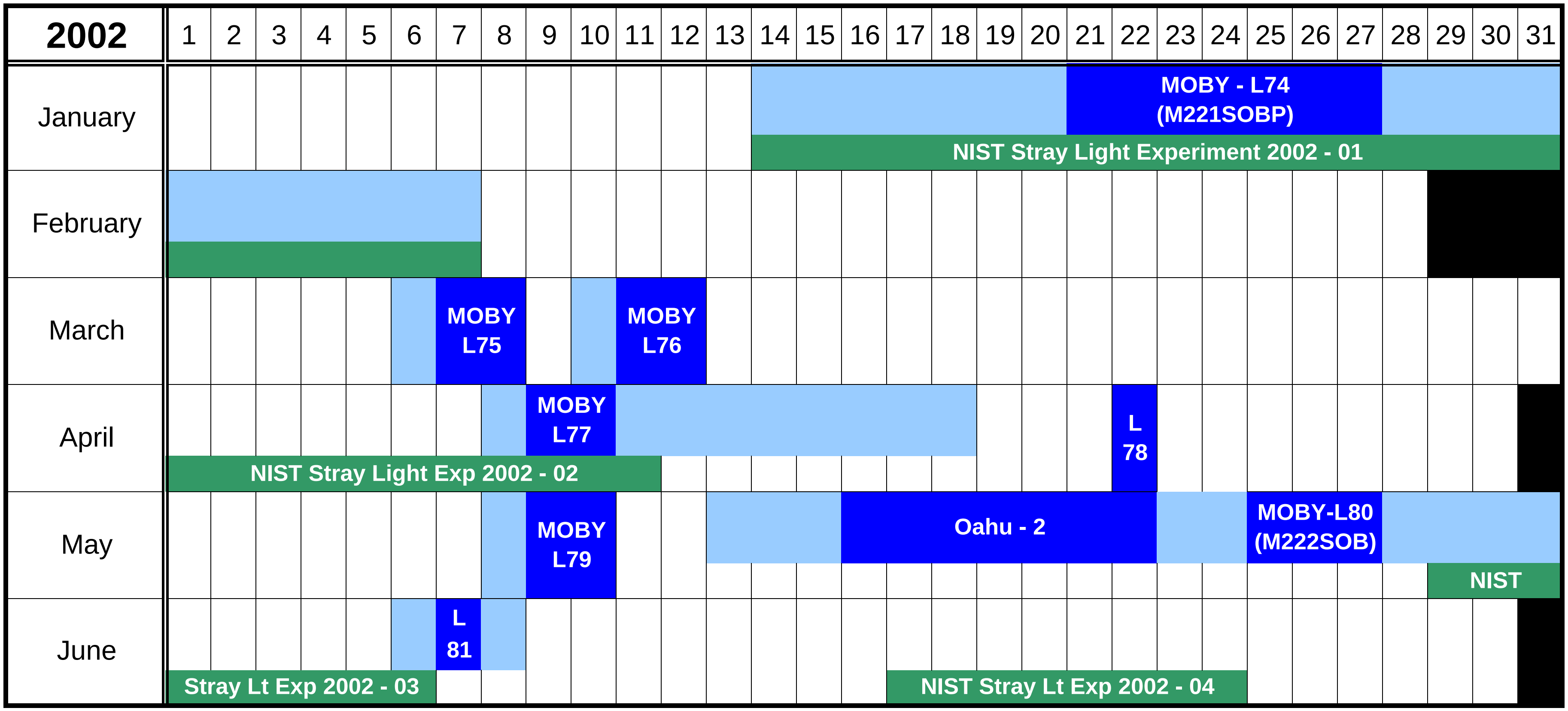


Figure 1

Appendix 1: Calibrations and maintenance schedules for MLML standards and instruments

• <u>SLM</u>

04-Jan-2002	Pre-L74	OL425-W6D100 after MOS205cfg06
10-Jan-2002	Pre-L74	OL425-W6D100 after MOS205cfg07
16-Jan-2002	NIST-2002-01	NPR-Lamp#3 after VXR
17-Jan-2002	NIST-2002-01	NPR-Lamp#1,2,3,4 & Lamp#3_only with VXR
17-Jan-2002	NIST-2002-01	OL425-W5 & W6D100 with VXR
18-Jan-2002	NIST-2002-01	OL425-W5 & W6D100 with VXR
18-Jan-2002	NIST-2002-01	OL420-W5 & W6D100 with VXR
17-Jan-2002	Pre-L74	OL425-W6D100 after MOBY219 LuB,M,T
18-Jan-2002	Pre-L74	GS5000-F454 after MOBY219 EuP,EdB,M,T,S
21-Jan-2002	Pre-L74	GS5000-F454 after MOBY219 EdT,S
31-Jan-2002	Post-L74	OL425-W6D100 after MOBY218 LuB,M(no Top Arm)
06-Mar-2002	Post-L74	OL425-W6D100 after MOBY218 LuB
07-Mar-2002	Post-L74	GS5000-F454 after MOBY218 EuP,EdB,M,S
12-Mar-2002	Post-L74	OL425-W6D100 after MOS204cfg06 LuMOS
16-Mar-2002	Post-L74	OL425-W6D100 after MOS202cfg08 LuMOS
20-Mar-2002	Post-L74	GS5000-F453 after MOS202cfg8& SIS101cfg04
10-May-2002	Post-L74	OL425-W6D100 after MOBY220 LuB,M,T
16-May-2002	Post-L74	GS5000-F454 after MOBY220 EuP
17-May-2002	Post-L74	GS5000-F471 after MOBY220 EuP,EdB,M,T,S
31-May-2002	Post-L80	GS5000-F453 after FOS/YSKim
31-May-2002	Post-L80	OL425-W6D100 after FOS/YSKim
04-Jun-2002	Post-L80	OL425-W6D100 after FOS/YSKim
06-Jun-2002	NIST-2002-03	GS5000-GS0910 during FOS/YSKim

• <u>SIS101</u>

20-Mar-2002	Post-L74	SIS101cfg04 Es via GS5000-F453
10-Apr-2002	NIST-2002-02	SIS101cfg04 Es via XS-R6G 578:617nm InBand
10-Apr-2002	NIST-2002-02	SIS101cfg04 Es via XS-R6G 593nm BaseLine

• <u>MOS202</u>

15-Mar-2002	Post-L74	MOS202cfg08 Lu via Ne, HgA
16-Mar-2002	Post-L74	MOS202cfg08 Lu via OL425-W6D100
20-Mar-2002	Post-L74	MOS202cfg08 Ed via GS5000-F453

• <u>MOS204</u>

12-Mar-2002	Post-L74	MOS204cfg06 Lu via OL425-W6D100 << Pos-B218 / Pre-B20 >>

• <u>MOS205</u>

04-Jan-2002	Pre-L74	MOS205cfg06 Lu via HgA, Ne
04-Jan-2002	Pre-L74	MOS205cfg06 Lu via OL425-W6D100 << Post-MOB217 >>
10-Jan-2002	Pre-L74	MOS205cfg07 Lu via OL425-W6D100 << Pre-MOB219 >>
11-Jan-2002	NIST-2002-01	MOS205cfg07 Lu via CS-

PER/I700/BG28/BG39/I400/I750

Appendix 1: (continued)

• MOBY218

31-Jan-2002	Post-L74	LuB,M(no Top arm) via OL425-W6D100
06-Mar-2002	Post-L74	LuB via OL425-W6D100
07-Mar-2002	Post-L72	EdB,M,S(no Top Arm, no Eu signal) via GS5000-F454
01-Feb-2002	NIST-2002-01	LuMid: XS-Ti:S 701:755 nm, 645,660,675,690 nm Diode Lasers
02-Feb-2002	NIST-2002-01	LuBot: XS-Ti:S 703:760 nm, 412,440,645,660,675,690 nm D.L.
03-Feb-2002	NIST-2002-01	LuBot: * nm Ar+ Laser, XS-Nd:V 532 nm
05-Feb-2002	NIST-2002-01	LuBot: Saturation check Via Ar+ and 690 nm Diode Laser
06-Feb-2002	NIST-2002-01	LuBot & LuMid: Saturation check Via Ar+ and 690 nm Diode L.

• MOBY219

17-Jan-2002	Pre-L74	LuB,M,T via OL425-W6D100
18-Jan-2002	Pre-L74	EuP,EdB,M,T,S via GS5000-F454
21-Jan-2002	Pre-L74	EdT,S via GS5000-F454
19-Jan-2002	NIST-2002-01	LuTop: CS-BG28/PER/I700/I750/I400
20-Jan-2002	NIST-2002-01	LuTop: XS-Ti:S 700:795 nm == RAG Reflection Peaks
23-Jan-2002	NIST-2002-01	LuTop: Diode Lasers 660,675,690
23-Jan-2002	NIST-2002-01	LuTop: XS-Doubled_Ti:S 428:438 nm == BSG Reflection Peaks

• MOBY220

04-Apr-2002	NIST-2002-02	LuMid: OL420/CS-BG28,PER,I750,I400,BG28
05-Apr-2002	NIST-2002-02	LuMid: Ar+ Saturation
06-Apr-2002	NIST-2002-02	LuMid: Ar+, Diode Lasers, XS-R6G Reflect Peaks
07-Apr-2002	NIST-2002-02	LuMid: XS-R6G Saturation
09-Apr-2002	NIST-2002-02	LuMid: Diode Lasers, XS-R6G Reflect Peaks, Images

10-Apr-2002	NIST-2002-02	LuMOS: XS Saturate, Ar+, Diode Laser Reflect Peaks
10-May-2002	Post-L74	LuB,M,T via OL425-W6D100
16-May-2002	Post-L74	EuP via GS5000-F454
17-May-2002	Post-L74	EuP,EdB,M,T,S via GS5000-F471

MODIS Data Product Status
Numbers 19, 23, & 26

Dennis K Clark

18 December 2001

MODIS Terra-Product Status

- Product 19
  - Parameter 13 - CZCS_pigment
    - (Chl *a* +Phaeo) Fl determined
  - Parameter 14 - chlor_MODIS
    - (Chl *a* (monovinyl and divinyl), Chl *a* allomer, Chl *a* epimer, and chlorophyllide *a*) - HPLC determined
  - Parameter 15 - pigment_c1_total
    - (Chl *a* + 27 Accessory Pigments) - HPLC determined

Product Status cont'd

- Product 23
    - Parameter 19 - Total Suspended Matter
        - Dry Weight

- Product 26
    - Parameter 23 - K_490
    - SeaWiFS - Downwelled Irradiance Diffuse Attenuation Coefficient

Computational Forms

- Products 19 and 23
  - Least Squares Regressions (Log, Log)
  - 3rd order polynomials
  - $R^2 > 0.91$ $S_{yx} \sim .045$
- Product 26
  - Least Squares Regression
  - Linear
  - $R^2 = 0.94$ $S_{yx} = 0.167$

Generalized form for product computation

Log Product = A(Log X)3 + B(Log X)2 + C(Log X) + D) / E

Where:

A,B,C,D are least squares regression coefficients,

E is a constant for offsetting the derived relationship (presently set to 1),

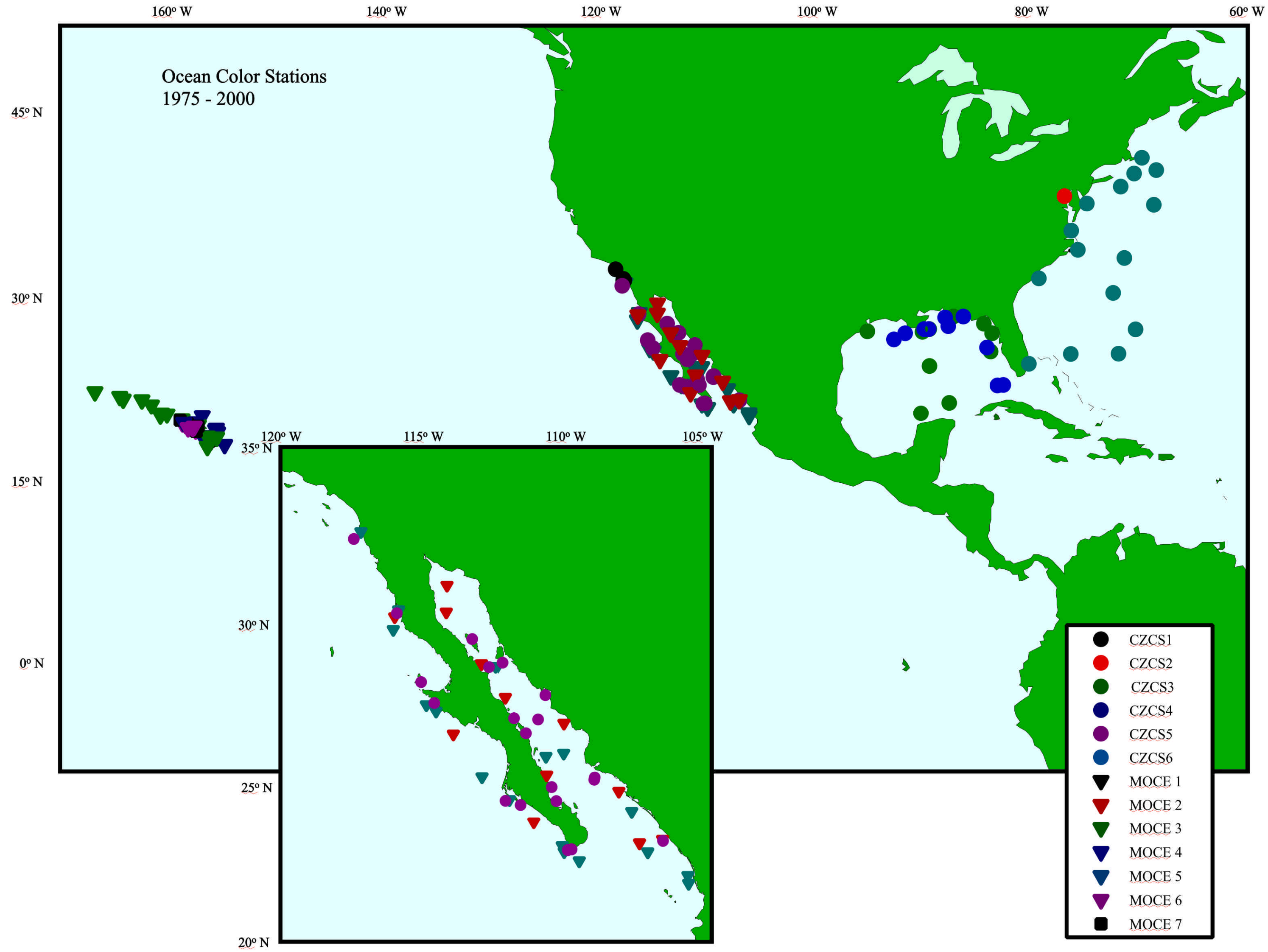
X = [(e) nLw (band 9) + (f) nLw (band 10) + (g) nLw (band 11)] / nLw (band 12),

The wavelength bands 9, 10, 11, & 12 are centered at 442, 487, 530, & 547 nm, respectively.

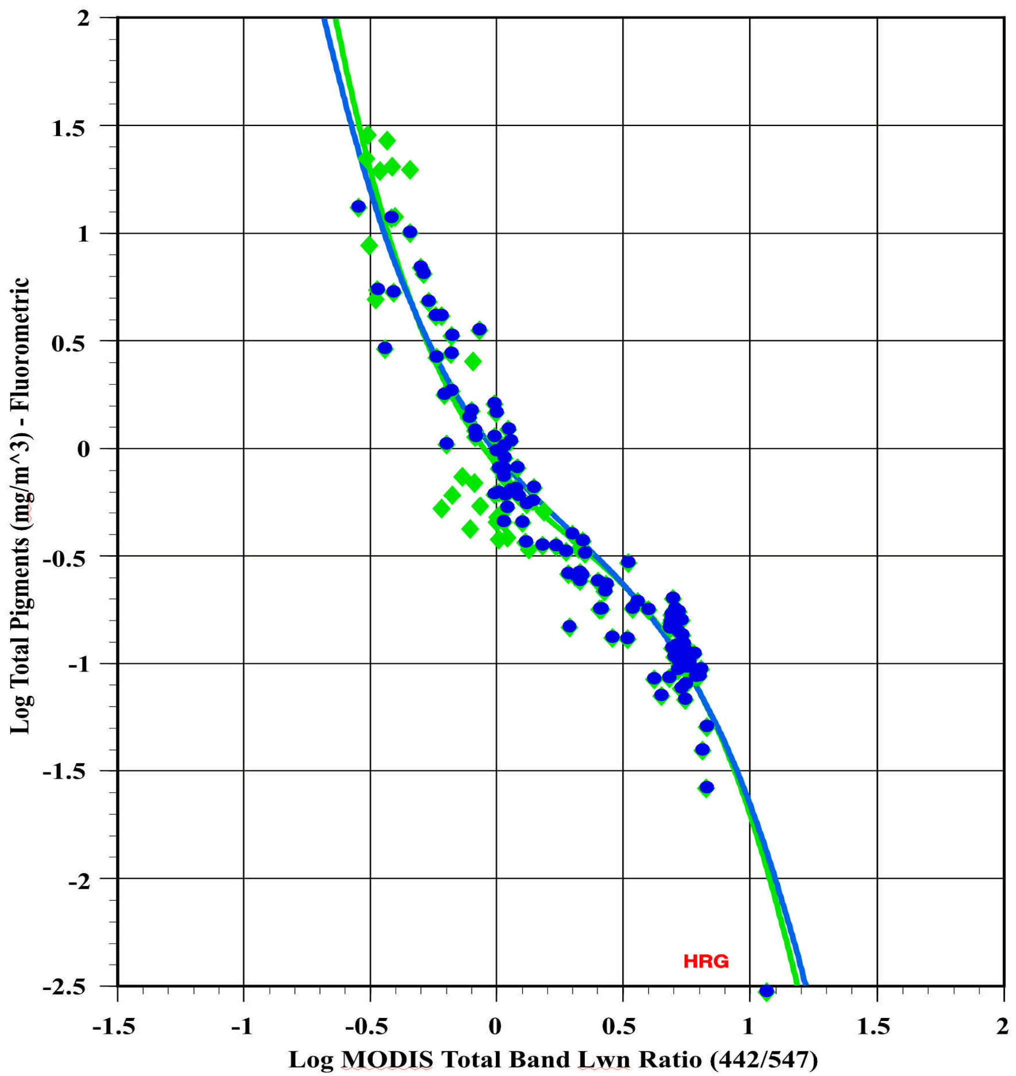
e, f, and g are set to zero or one to select band combinations,

nLw = MODIS total band solar normalized water-leaving radiance.

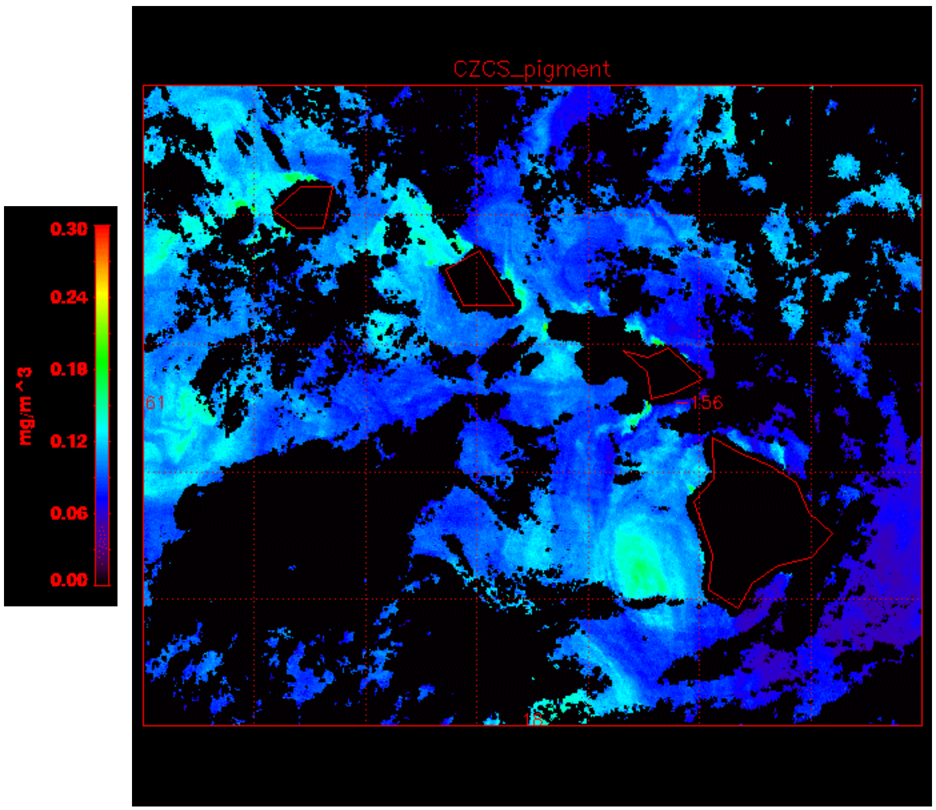
Station location map for the observations used in development of these products.

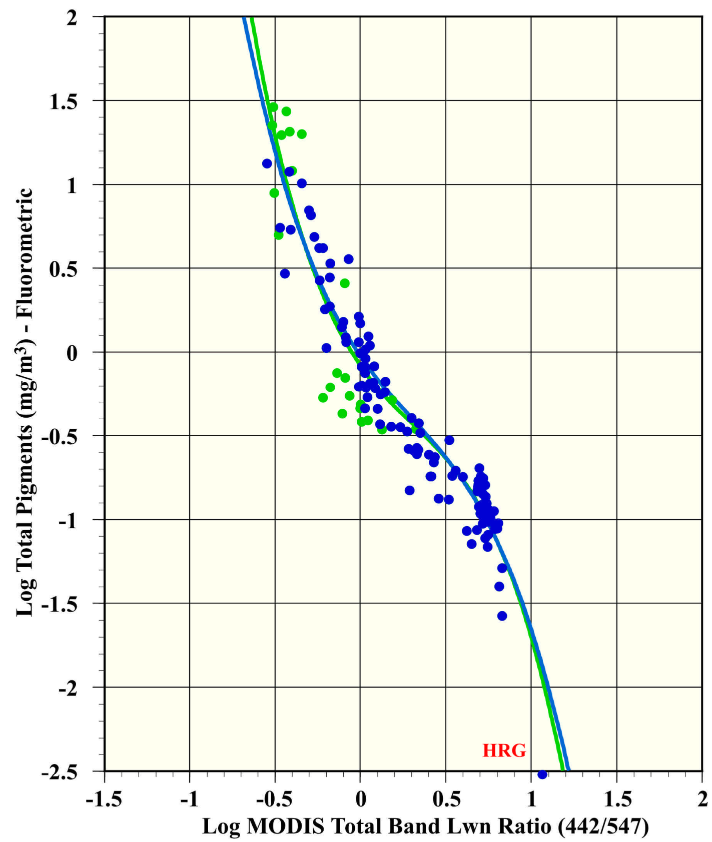


CZCS_pigment - MODIS total band normalized water-leaving radiance ratios vs fluorometrically determined pigment concentrations (mg/m3) with regression lines for case 1 waters (blue) and case 1 & 2 (green) waters.



Product Number - MOD 19
Parameter 13, CZCS_pigment
Day 345, 2000

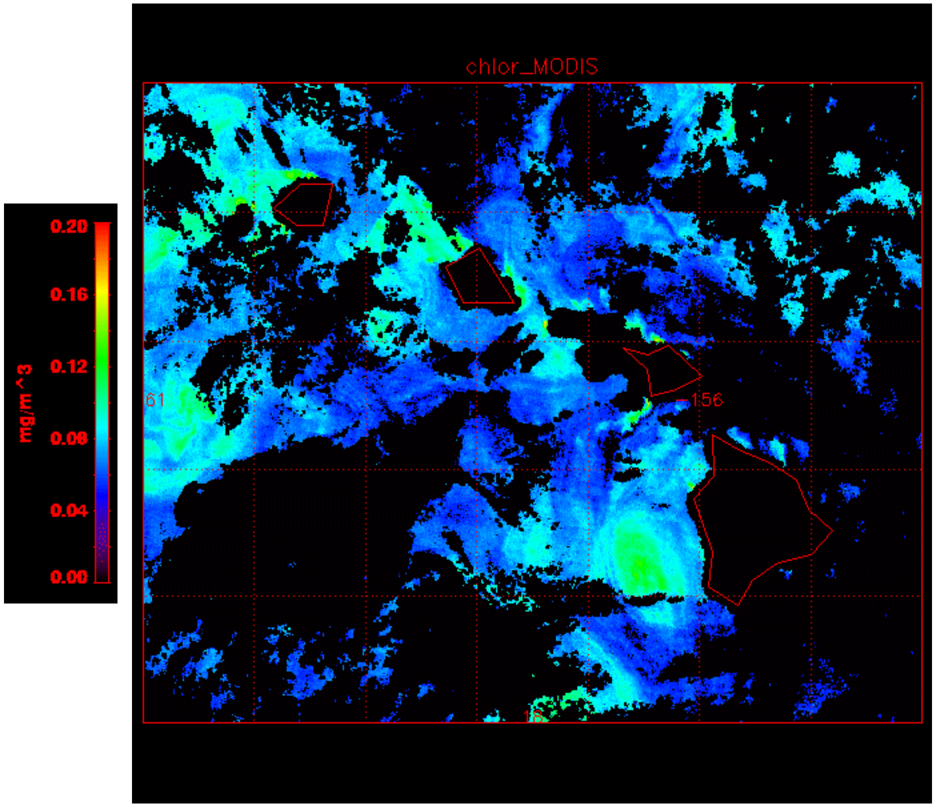


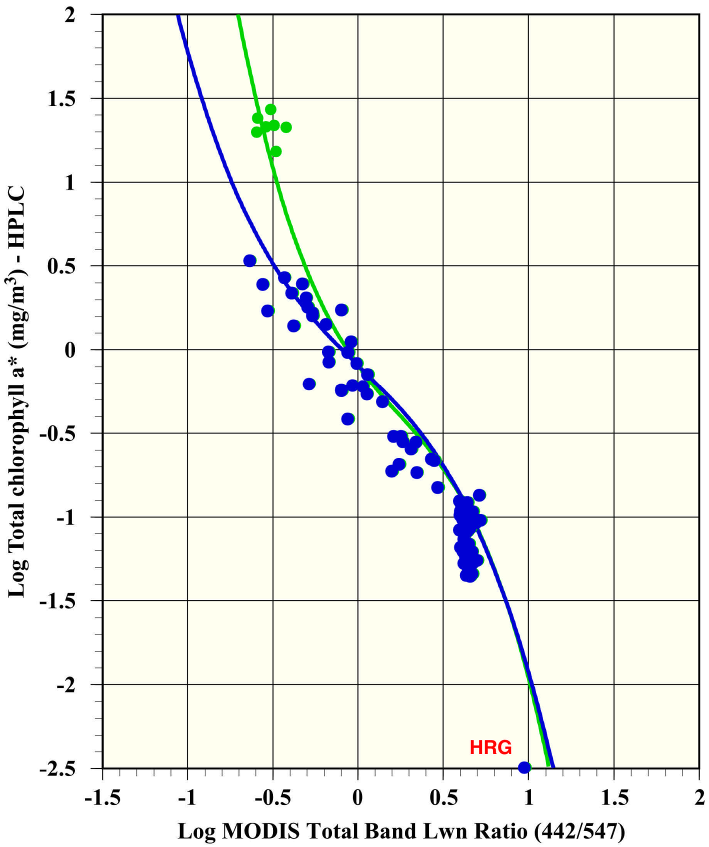


f(x) = -1.742E+0*x^3 + 1.625E+0*x^2 + -1.495E+0*x + -7.938E-2
R0^2 = 9.116E-1

f(x) = -1.338E+0*x^3 + 1.213E+0*x^2 + -1.497E+0*x + -2.273E-2
R0^2 = 9.207E-1

Product Number - MOD 19
Parameter 14, chlor_MODIS
Day 345, 2000

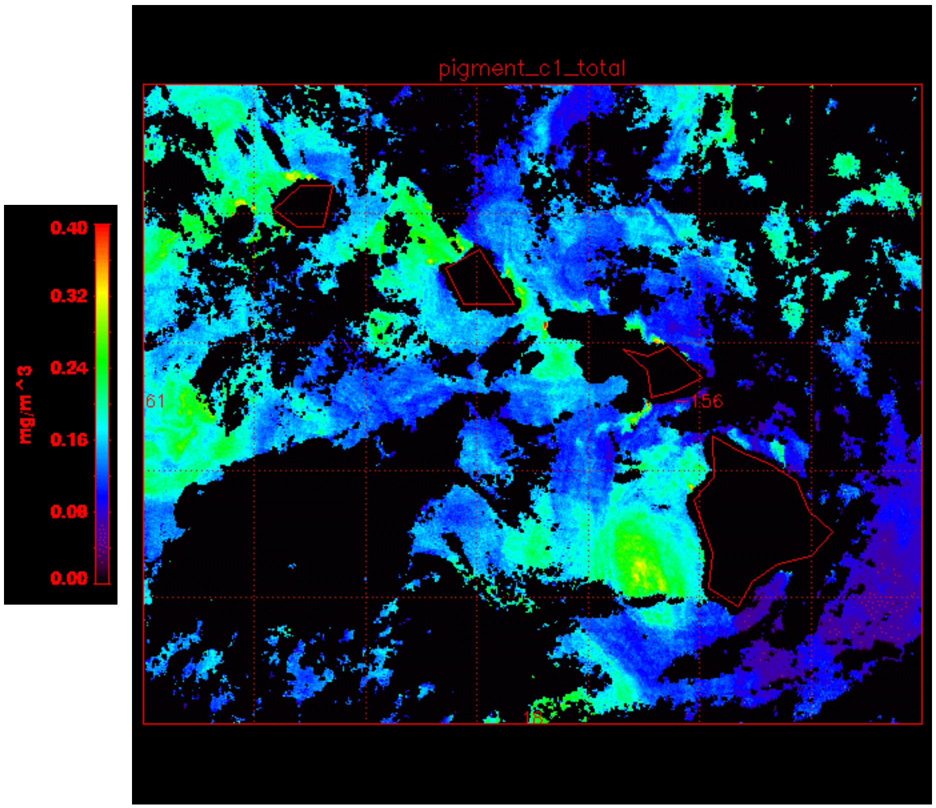


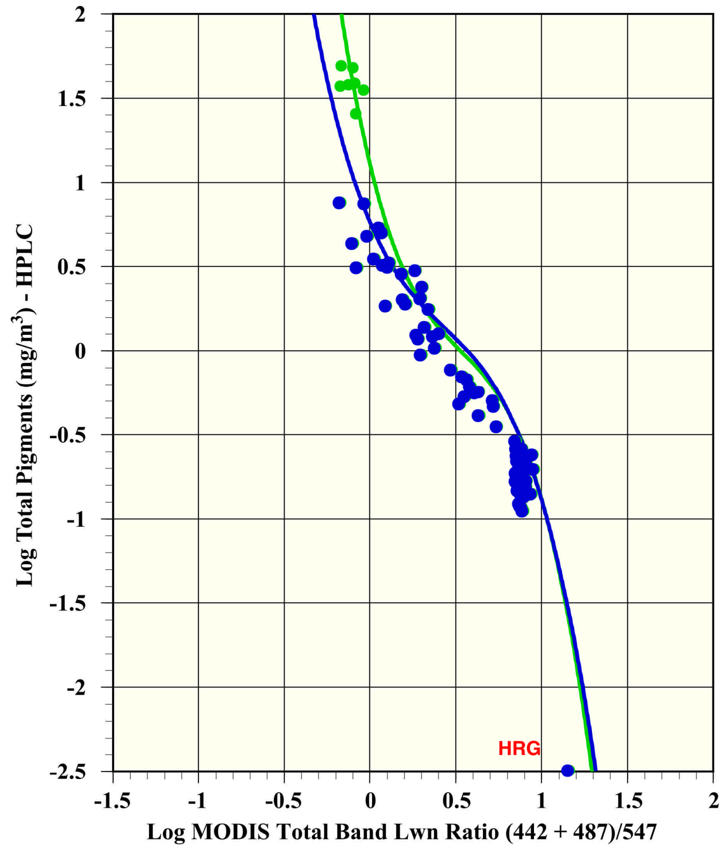


f(x) = -1.594E+0*x^3 + 1.122E+0*x^2 + -1.396E+0*x + -9.221E-2
R0^2 = 9.153E-1

f(x) = -8.622E-1*x^3 + 1.953E-2*x^2 + -9.883E-1*x + -9.318E-2
R0^2 = 9.361E-1

Product Number - MOD 19
Parameter 15, pigment_cl_total
Day 345, 2000

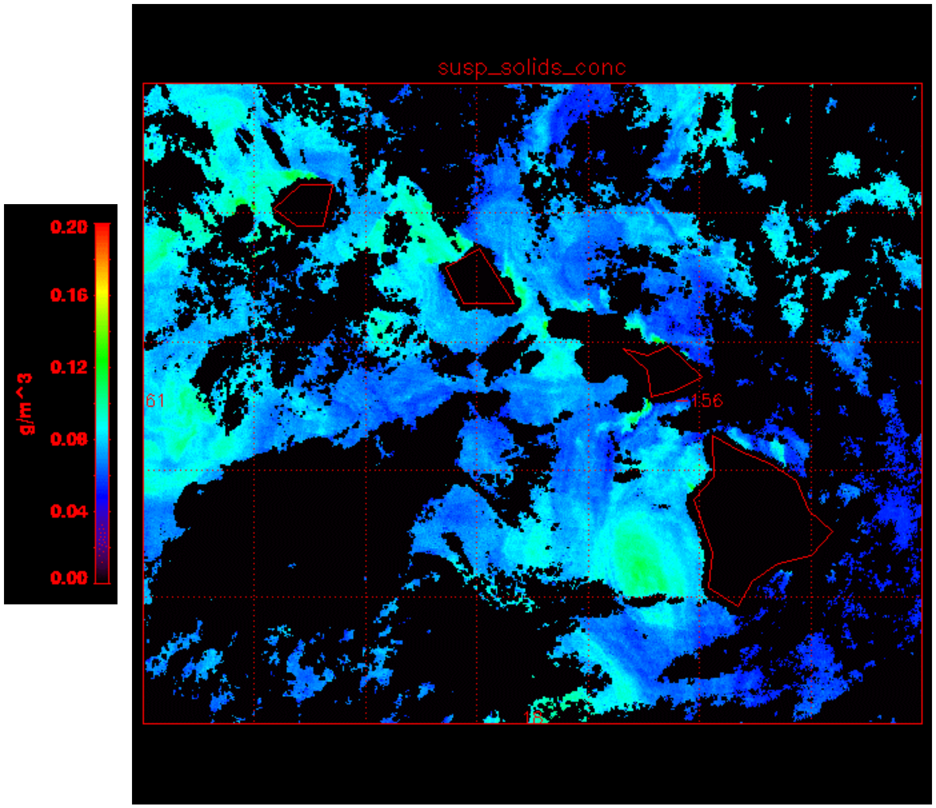


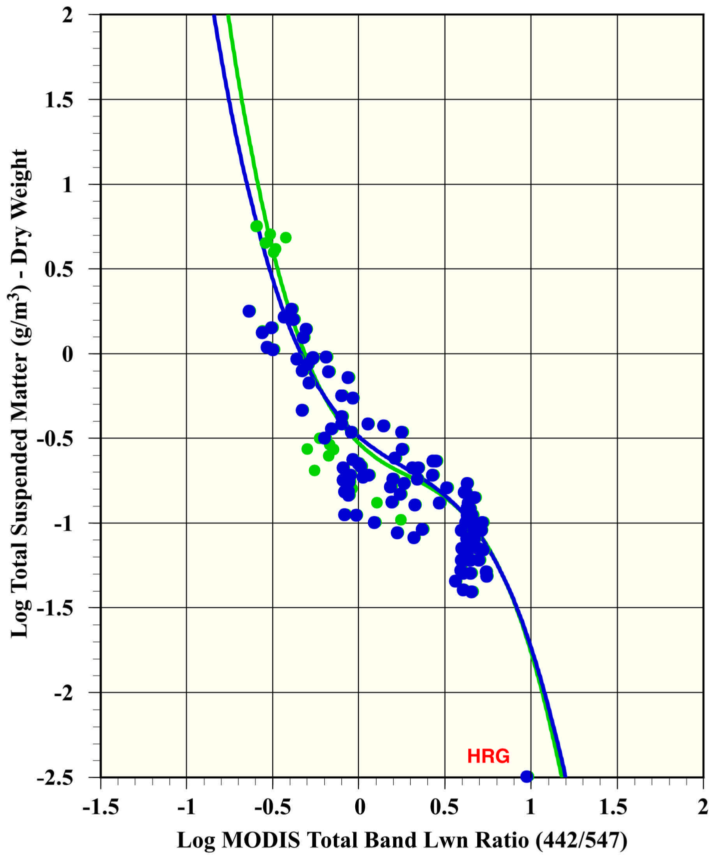


f(x) = -3.848E+0*x^3 + 6.106E+0*x^2 + -4.250E+0*x + 1.109E+0
R0^2 = 9.341E-1

f(x) = -2.550E+0*x^3 + 3.292E+0*x^2 + -2.393E+0*x + 7.644E-1
R0^2 = 9.396E-1

Product Number - MOD 23
Parameter 19,Total Suspended Matter
Day 345, 2000

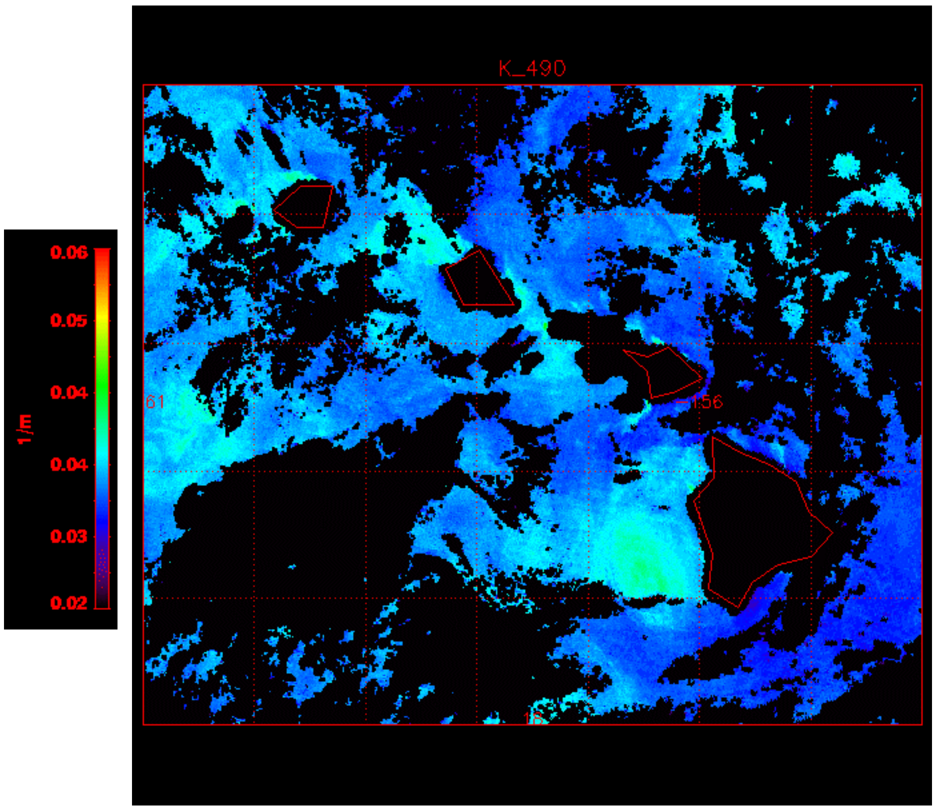


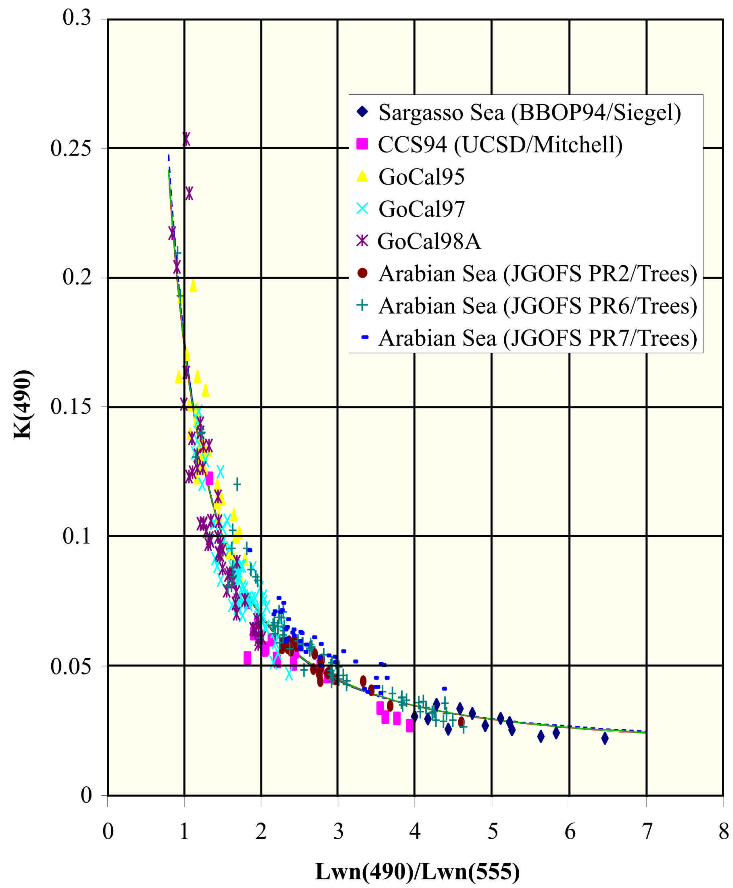


f(x) = -1.902E+0*x^3 + 1.659E+0*x^2 + -9.883E-1*x + -5.307E-1
R0^2 = 8.309E-1

f(x) = -1.513E+0*x^3 + 1.170E+0*x^2 + -9.002E-1*x + -4.901E-1
R0^2 = 7.977E-1

Product Number - MOD 26
Parameter 23,K_490 Diffuse Coefficient
Day 345, 2000

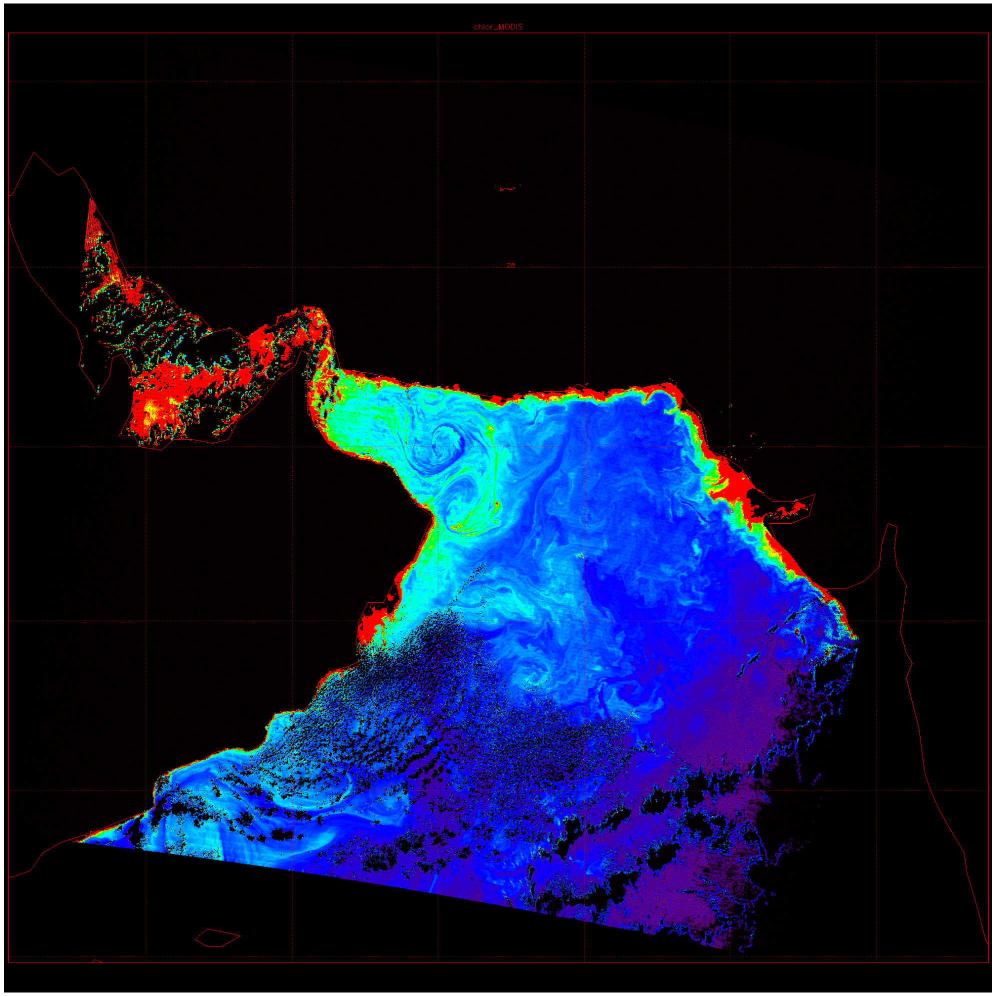




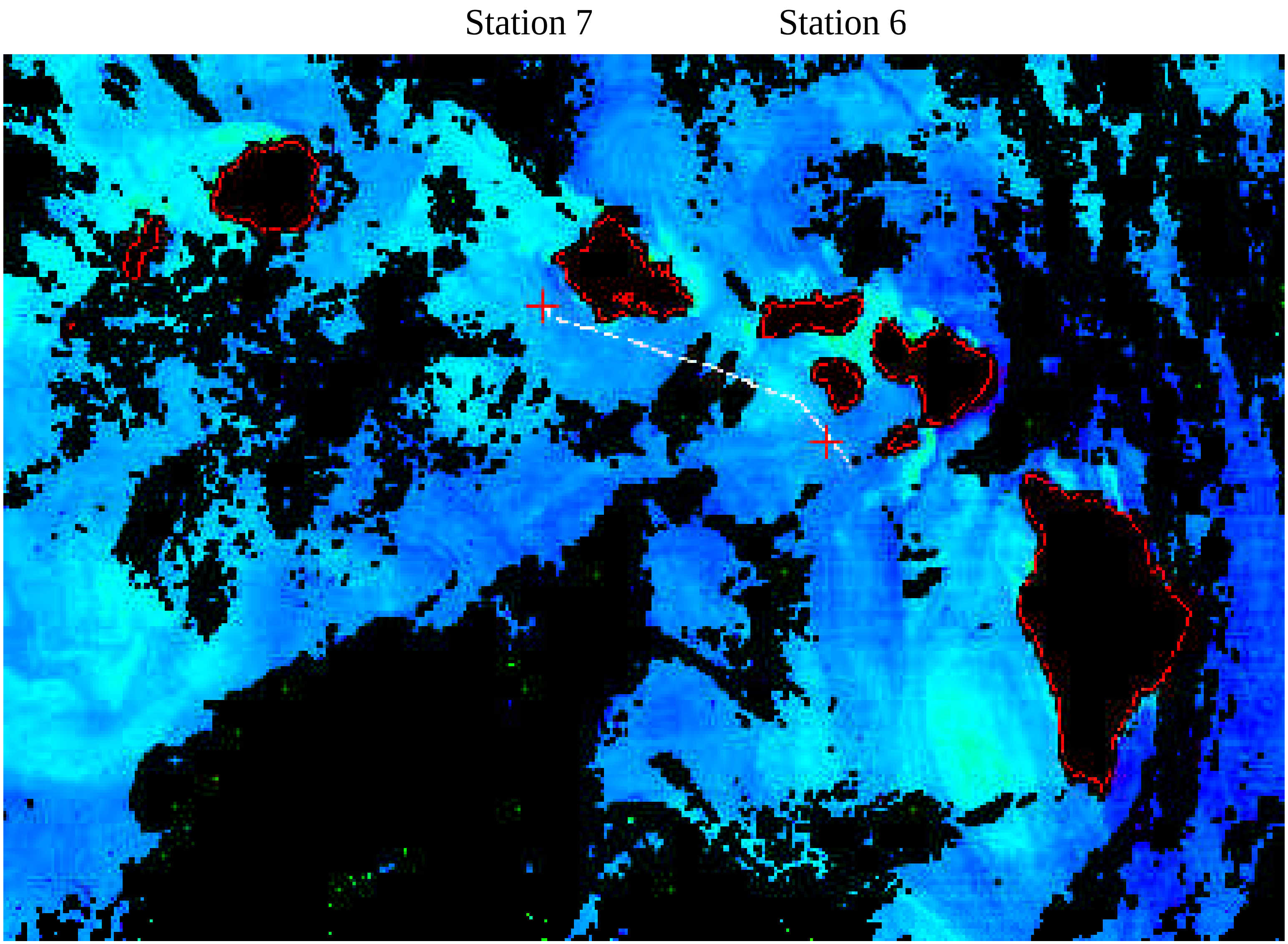
$$K_{Ed}(490) = 0.016 + 0.15645\left[\frac{nL_w(488)}{nL_w(547)}\right]^{-1.5401}$$

R0^2 = 9.4E-1

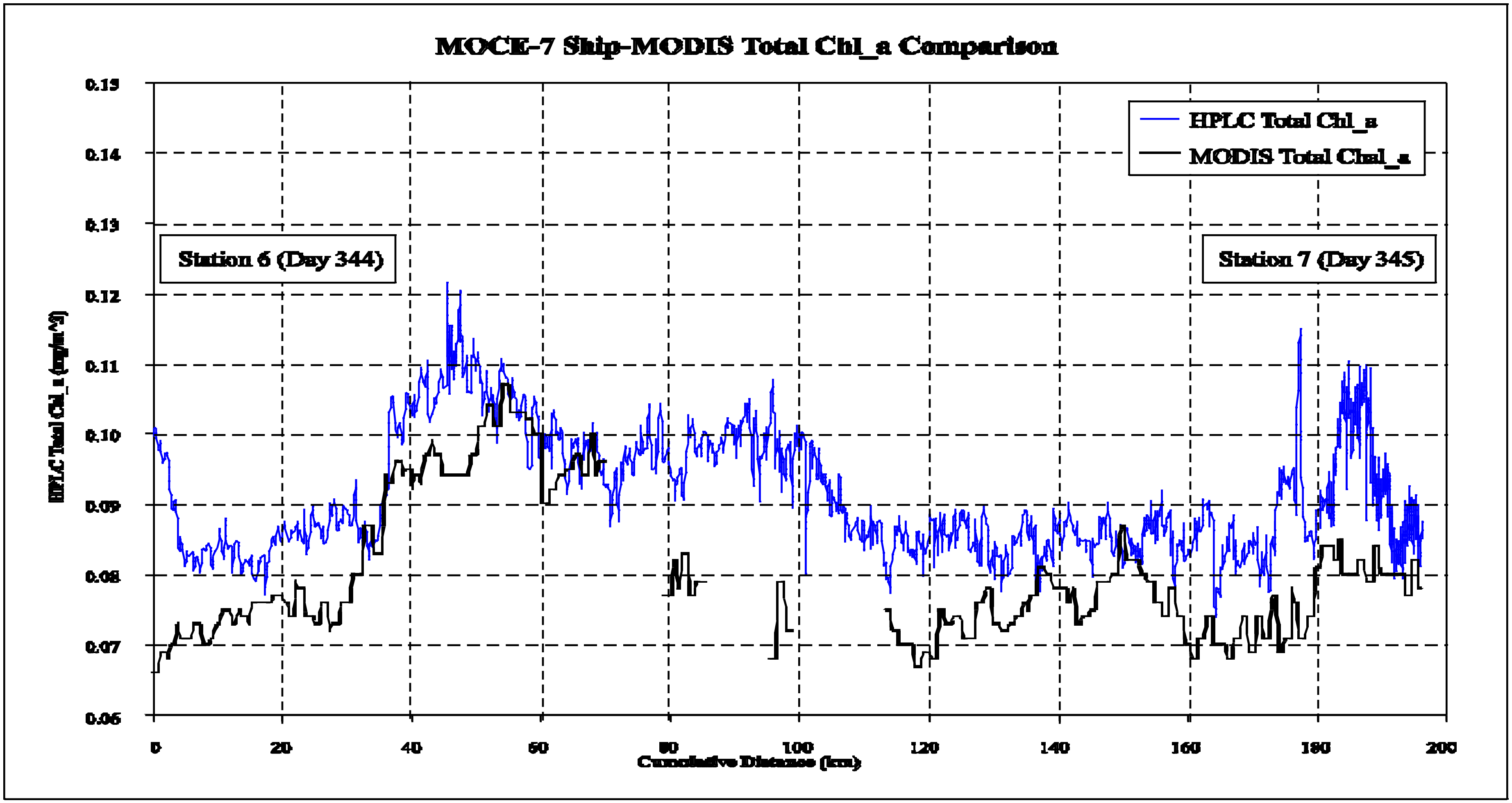
Product Number - MOD 19
Parameter 14, Chlor_MODIS
Arabian Sea Dec. Chl (Day 336, 2000)



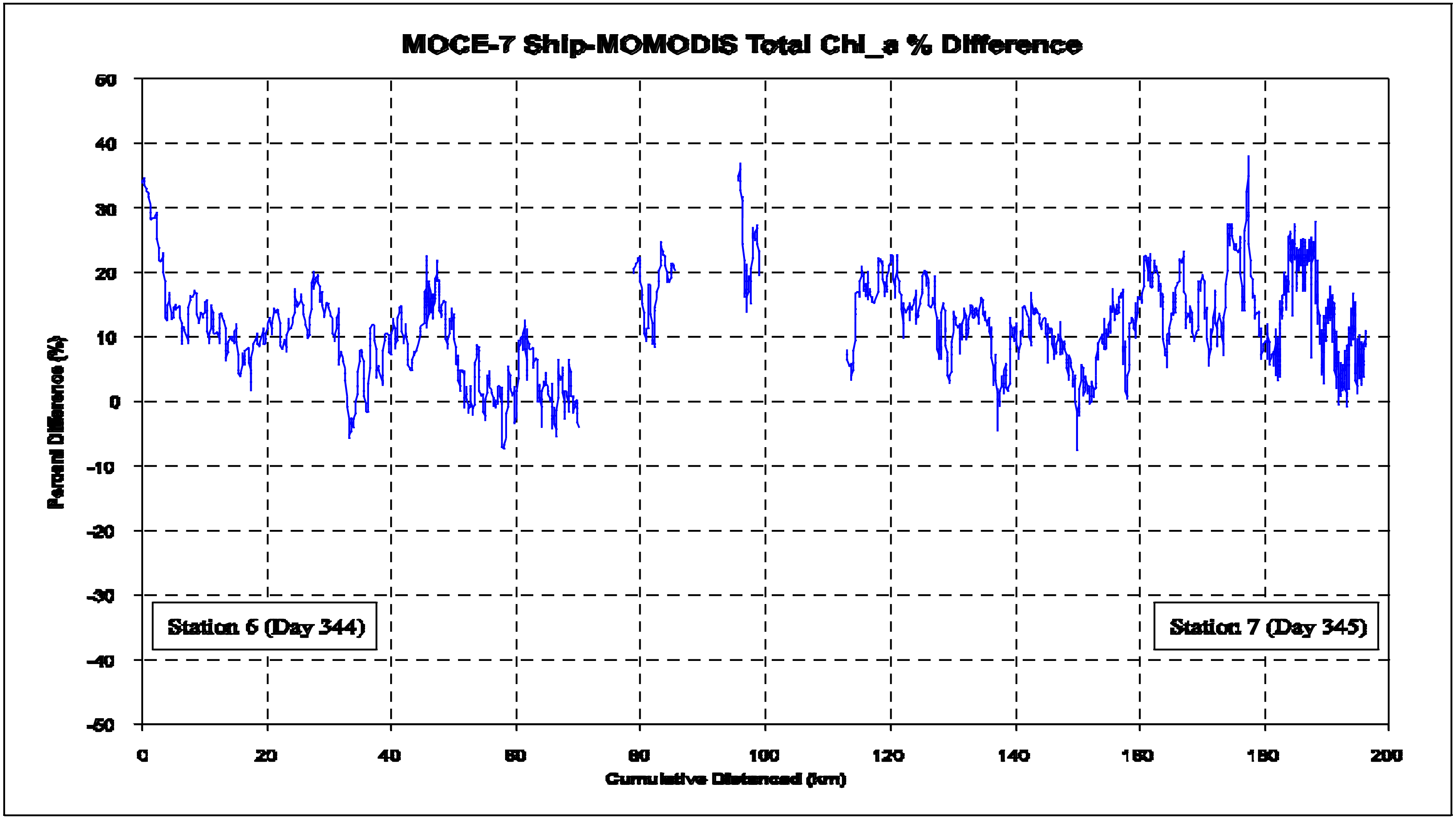
MODIS Day 345 -Ship Track



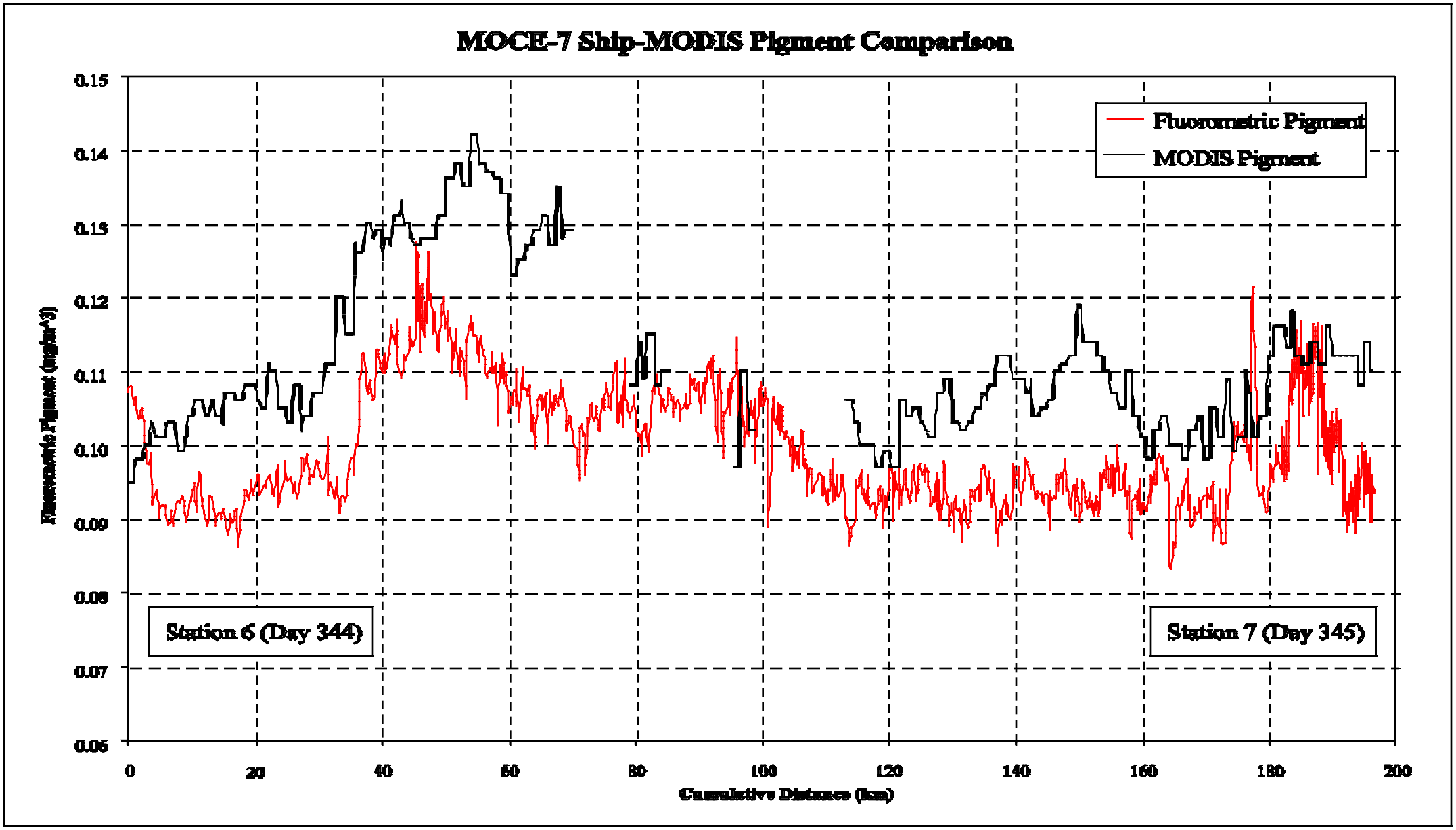
MODIS_CHL Retrievals - MOCE -7 along track Total chl a



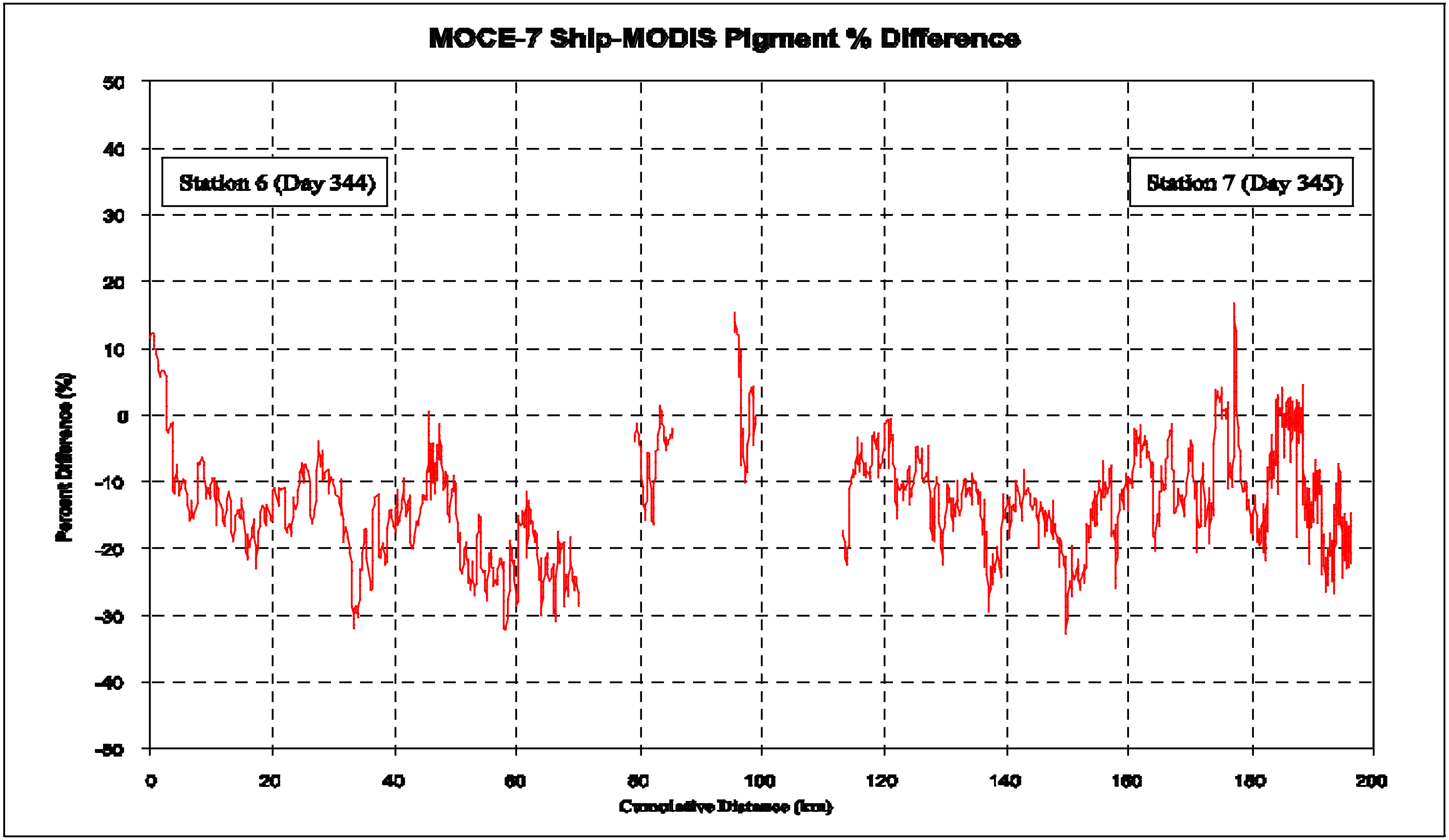
Percent Difference



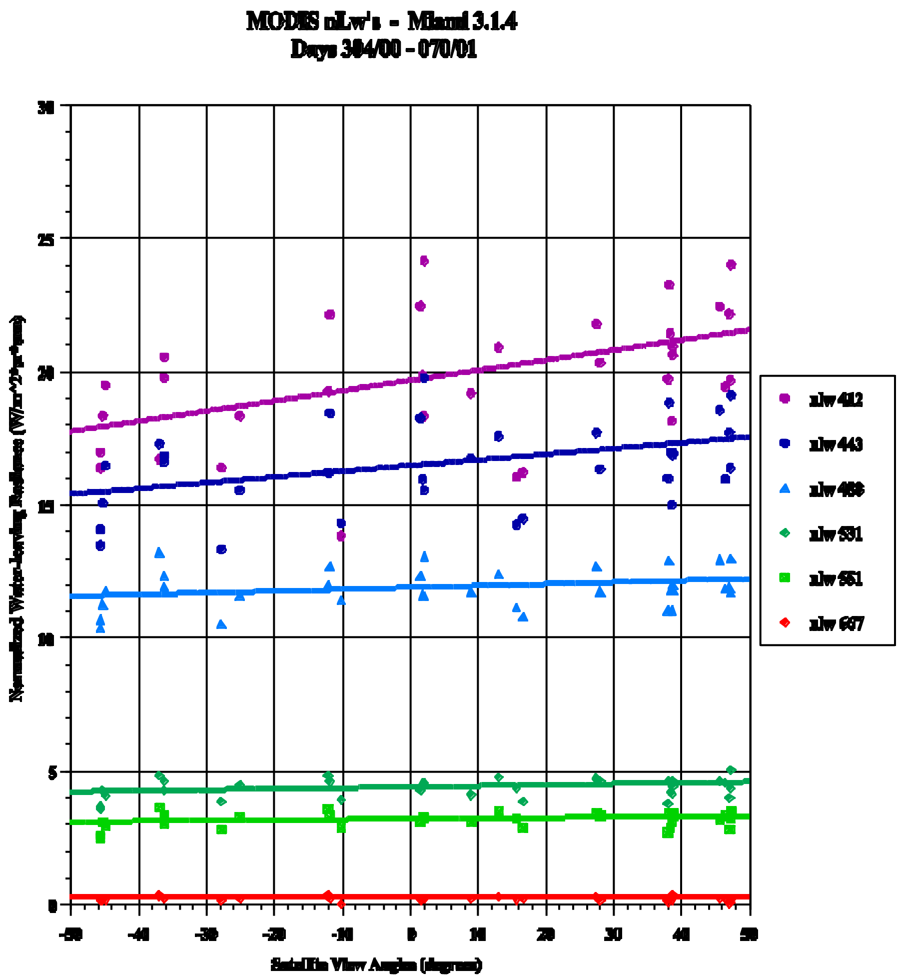
MODIS CZCS_pigment - MOCE-7 along-track pigments

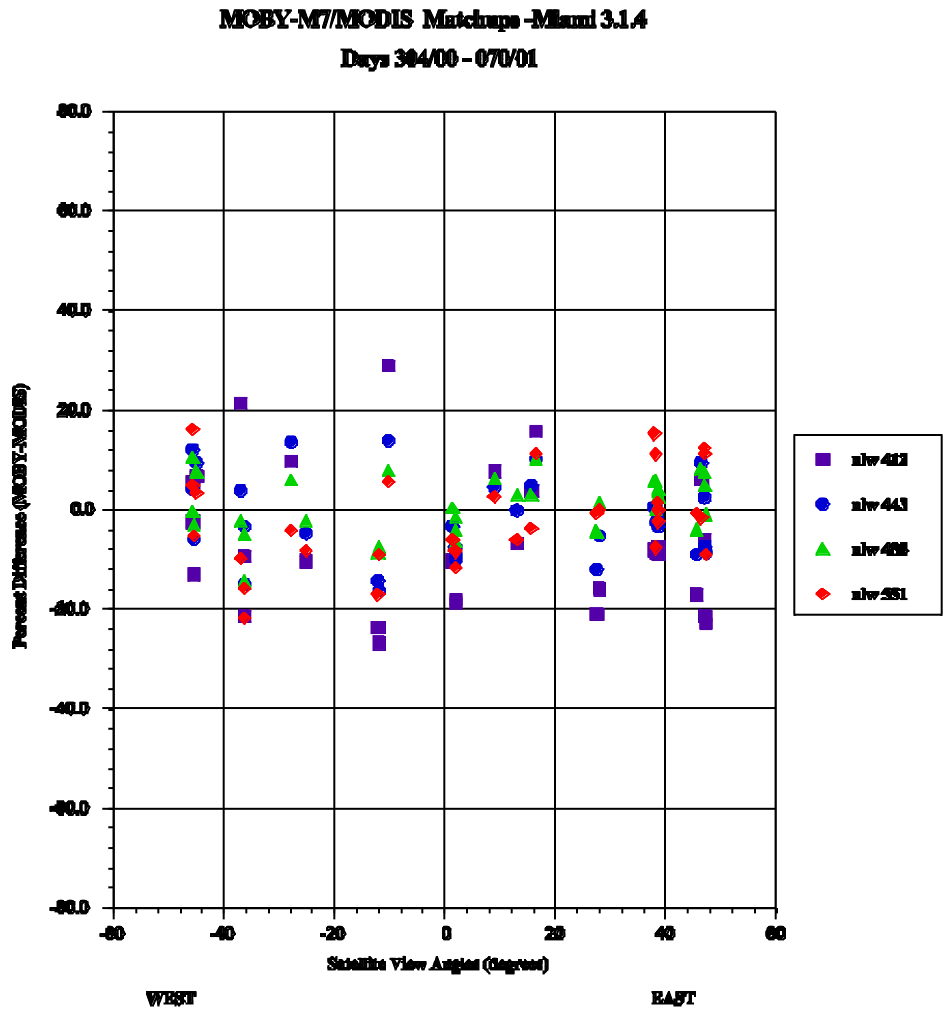


Percent Difference



Calibration State Version 3.1.4





Present Status - Future Validation

- Present products invalid with the exception of ~ 2-3 weeks in December 2000
- Recent Miami calibration results solve most of the major nLw problems
- These products could be validated within 30 days once the nLw's are considered validated.

Appendix 3: History of NOAA/MLML Marine Optical System (MOS) Observations.

Cruise: MOBY-L74, Ship: R/V Ka'imikai-O-Kanaloa, Location: Hawaii (MOS202cfg08)

Station (#	Name)	Date (GMT)	Time (GMT)	Latitude (+North)	Longitude (+East)	Depths (dbar)
04a	MOBY Mooring II	23-Jan-2002	21:22	20.819	-157.206	1,2,3,5,9
04b	MOBY Mooring II	23-Jan-2002	22:37	20.835	-157.185	1,3,5

Appendix 4: L-74 SeaBird CTD Stations

Station	Position	Date (GMT)	Filename	Max. Depth
04, Moby Mooring	**20° 49.34'N 157° 11.64'W**	**00:30 (GMT) 24 Jan 2002**	**sbe0152p.mld**	**225**